FISHERY RESEARCH

# KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT

## ANNUAL PROGRESS REPORT
## April 1, 2000 – March 31, 2001


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**IDFG Report Number 02-10**
**April 2002**

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## Project Progress Report

### 2001 Annual Report


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To


U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97283-3621

Project Number 88-65
Contract Number 88-BI-93497

IDFG Report Number 02-10
April 2002

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## ABSTRACT

Due to low precipitation and snow pack (estimated at less than 50 percent of normal), as well as low reservoir levels in Lake Koocanusa, the U.S. Army Corps of Engineers refrained from generating power or releasing water from Libby Dam into the Kootenai River for most of the 2000-2001 winter. This situation provided a low flow test for burbot *Lota lota* migration. We documented burbot migrating and evidence to suggest spawning at the proper time in the Idaho portion of the drainage for the first time since our studies began in 1993. We also documented the migration of several gravid burbot into the Goat River, British Columbia (BC) at approximately the same time. We recorded 73 captures of burbot in Idaho and BC. A large majority of the captures (52) occurred at Ambush Rock (rkm 245) during a 19 d period from January 26 through February 13, 2001, during which gravid, flowing, and spent males and females were identified. The percentage of recaptures in our catch was very high (47%) and included several fish that were recaptured multiple times across years. During the post-spawn period of 2000-2001, 10 sonic-tagged burbot exhibited downstream, sedentary, and upstream movement patterns. The appearance of burbot at Ambush Rock during the spawning period, circumstantial evidence of spawning, and movements of tagged fish during the low flows support results of previous findings that high flows during winter inhibit burbot migration and spawning. We collected 22 blood samples for plasma steroid analysis from the Kootenai River population and 17 blood samples from the Columbia Lake population (the control). Our analysis of reproductive physiology showed no evidence of reproductive dysfunction during the winter of 2000-2001. Our research efforts indicated that burbot were able to develop reproductive products, migrate, and spawn normally under these low flow conditions. Whether spawning success or recruitment improved is unknown as no burbot larva were caught, despite considerable effort.



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## INTRODUCTION

In Idaho burbot *Lota lota* are endemic only to the Kootenai River (Simpson and Wallace 1983). Burbot in the Kootenai River (Figure 1) once provided an important winter fishery to residents of northern Idaho. Some anglers reported catching up to 40 burbot per night during winter setline fishing (Paragamian 1994). The annual harvest of burbot from the Kootenai River by sport and commercial fisherman in Idaho prior to 1972 may have been in the tens of thousands of kg. Three commercial anglers alone harvested an estimated 2,150 kg in 1958 (Idaho Department of Fish and Game [IDFG] Regional Archives, unpublished). Burbot caught during the winter fishery are thought to have been part of a spawning migration from the lower river and Kootenay Lake in British Columbia (BC), Canada. However, after construction and operation of Libby Dam by the U.S. Army Corps of Engineers (USACE) in 1972, the fishery rapidly declined and was closed in 1992. Concomitant to the collapse in Idaho was the collapse of the burbot fishery in Kootenay Lake, BC (Paragamian et al. 2000). Operation of Libby Dam for hydroelectric power and flood control has created major changes in the river's seasonal flow, particularly during the winter when burbot spawn (Figure 2). The temperature regime and nutrient supply of the Kootenai River are also thought to be important factors for burbot spawning and recruitment; they too have changed since construction of Libby Dam (Partridge 1983; Snyder and Minshall 1996; Richards 1996).

The Kootenai River Fisheries Investigation was initiated in 1993 by the IDFG to document burbot abundance, distribution, size structure, reproductive success, and movement, and to identify factors limiting burbot in the Kootenai River. Few burbot were captured between rkm 246 (Bonners Ferry) and the Montana border (rkm 275) from 1993-1994 (Paragamian 1994). There has been little evidence of burbot reproduction in the Idaho reach. Only one juvenile burbot was captured from 1993-1998, and no larval fish were collected. However, numerous size-classes of burbot were in the catch, indicating some burbot were reproducing successfully. Previous studies have failed to document a spawning run of burbot from the lower river or Kootenay Lake, but cooperative sampling in the BC reach of the river with the Ministry of Environment Lands and Parks (BCMOELP) documented spawning burbot in the Goat River, BC.

Studies completed in the winter of 1997-1998 indicated flow management at Libby Dam likely affected burbot spawning migration during winter (Paragamian 2000). Movement of burbot with sonic transmitters was significantly higher ($P < 0.01$) during low flow test conditions, which were designed to replicate pre-dam Kootenai River flow. Movement upstream was also significantly higher during low flow tests than the control ($P = 0.009$), despite the fact there were low flows during the controls. Winter flows are now three to four times greater than they were historically, when conditions were relatively stable. Daily differences in flow now range up to 652 $m^3/s$. Fluctuating flows from Libby Dam, caused by hydropower production and floodwater evacuation, appear to have continuously disrupted upstream migrations of burbot. The specific effect of this disruption to burbot spawning migration and spawning is unknown, but it may have reduced spawning fitness or stamina or affected timing of burbot spawning. One or all of these possible factors could have been sufficient to reduce spawning success and recruitment.

To identify mechanisms that are reducing spawning success and recruitment, we initiated a study of the reproductive physiology of burbot in the Kootenai River. Normally, seasonal changes in environmental cues, such as temperature or photoperiod, initiate behavioral and physiological responses in fish prior to and during the spawning season (Moyle 1988). Changes in these cues are relayed from the nares, eyes, or other structures to the hypothalamus and pituitary that produce reproductive steroids necessary for final gonad development and successful spawning (Redding and Patiño 1993). In Missouri, DiStefano et al. (1997) compared the reproductive physiology of walleye *Stizostedion vitreum* from the tailwater of Harry S. Truman Dam that were subjected to an altered thermal and flow regime to walleyes from an unregulated segment of the North Fork of the White River. Their data indicated that walleyes in the tailwater of Truman Dam were reproductively dysfunctional and serum profiles of reproductive steroids were irregular when compared to walleye from the unregulated river segment and to other populations (the control population). Using a similar study design, we sought to compare reproductive steroids of burbot from the Kootenai River to those of a healthy, naturally-reproducing burbot population from Columbia Lake, BC, Canada. Burbot from Columbia Lake are thought to be similar to burbot from the Kootenai River in terms of spawning behavior and timing (Arndt and Hutchinson 2000) and acted as the control for our study. The Columbia Basin Fish and Wildlife Compensation Program through the cooperation of the BCMOELP operated a weir on the primary spawning tributary during winter that facilitated blood collection from post-spawn burbot.

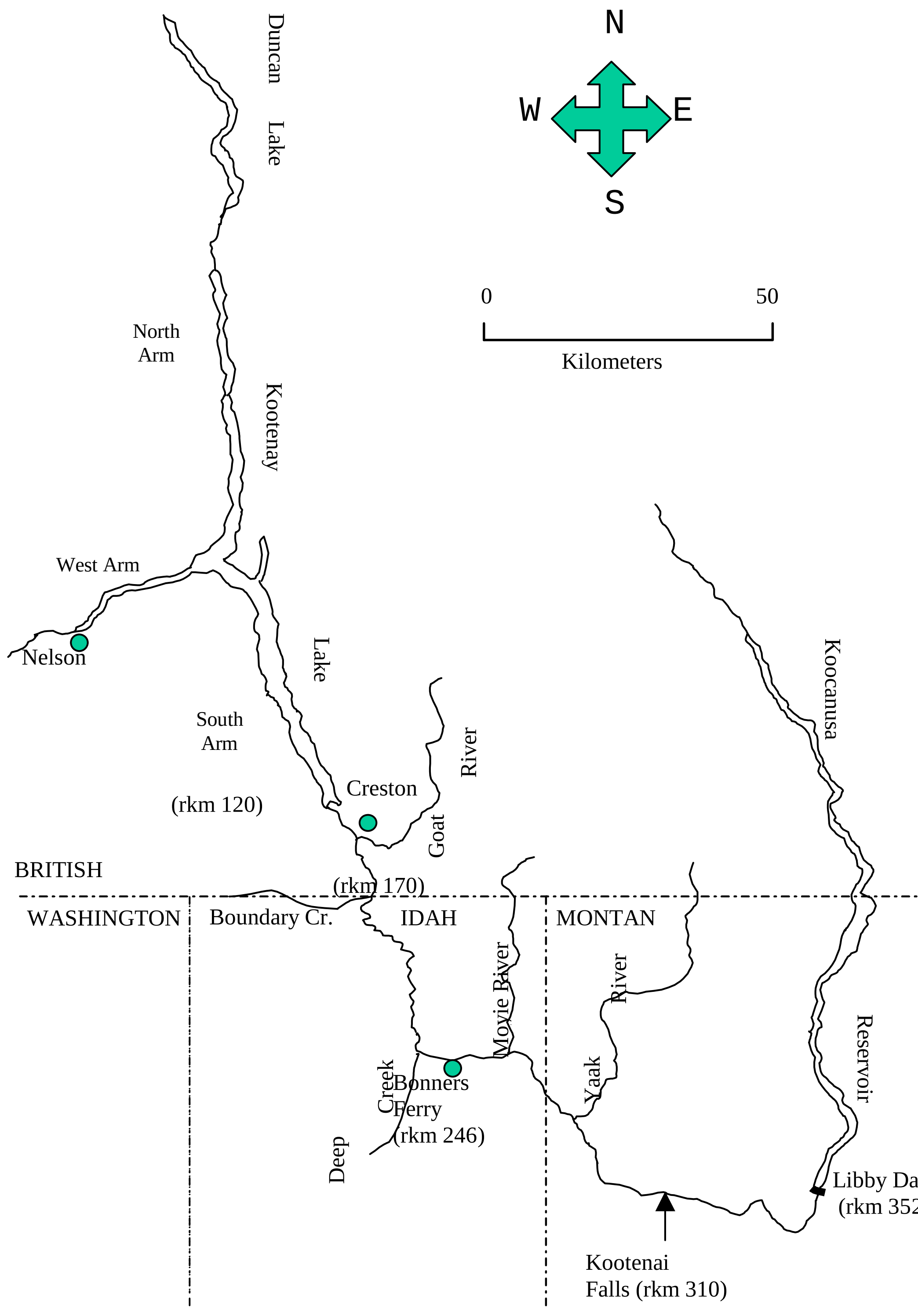


Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important access points.

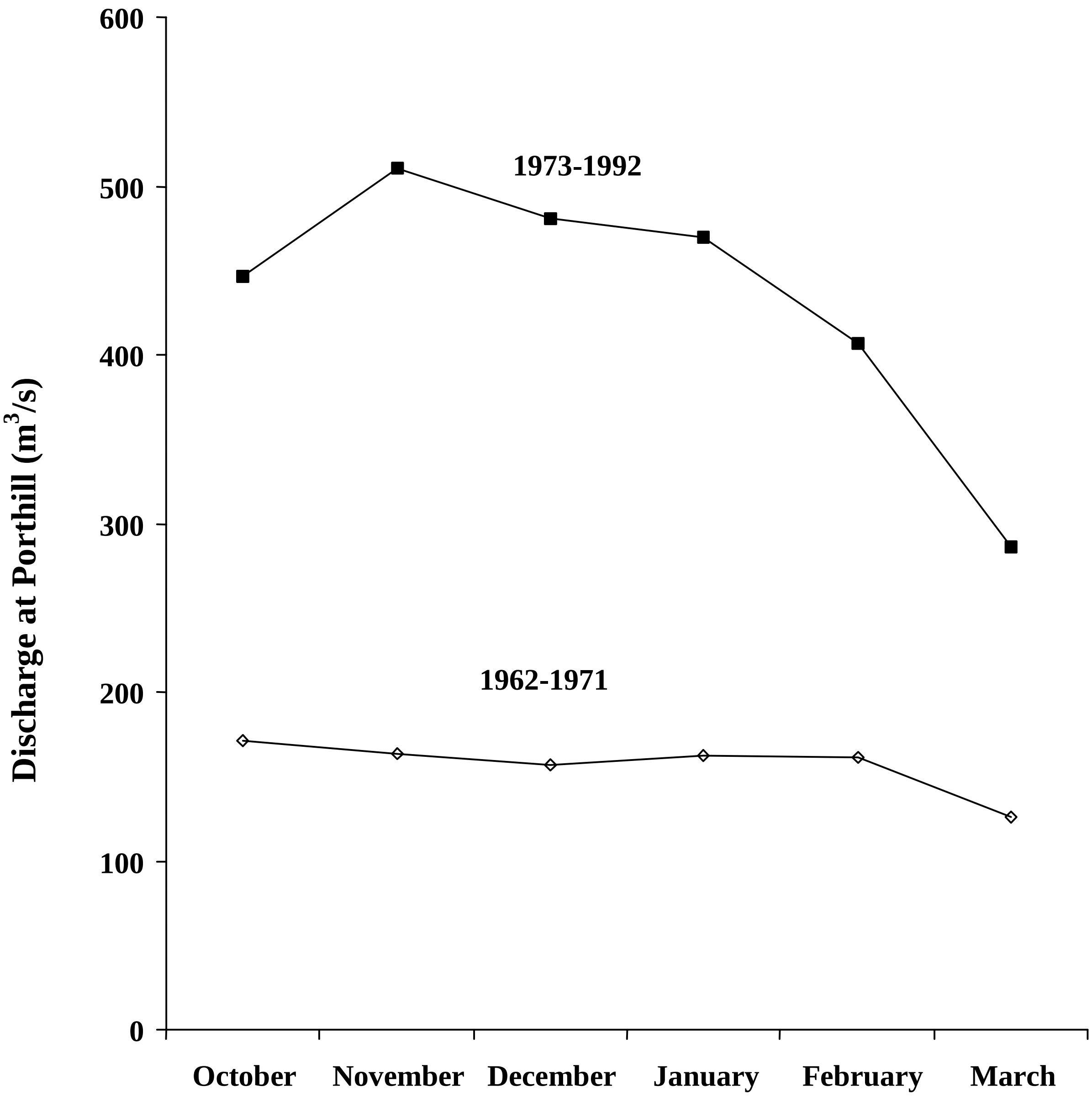


Figure 2. Mean monthly discharge of the Kootenai River at Porthill, Idaho, from 1962 through 1971 (pre-Libby Dam), and from 1973 through 1992 (post-Libby Dam).

## GOAL

The management goal of this study is to restore the burbot population in the Idaho reach of the Kootenai River and improve fishing success to historic levels.

## OBJECTIVES

1. Identify factors limiting burbot within the Idaho portion of the Kootenai River drainage and recommend management alternatives to restore the fishery to self-sustainable levels.

2. Define factors limiting burbot migration and reproductive success to improve survival and recruitment of young burbot.

3. Test the null hypothesis ($H_o$) that winter operation of Libby Dam does not affect burbot migration distance or travel rate.

4. Determine if there is a stress relationship between flow in the Kootenai River and burbot reproductive physiology by comparing plasma steroids of burbot from the Kootenai River and a control population in Columbia Lake, BC.

## STUDY AREA

The Kootenai River (spelled Kootenay for Canadian waters) is one of the largest tributaries to the Columbia River. Originating in Kootenay National Park, BC, the river flows south into Montana, where Libby Dam impounds water into Canada and forms Lake Koocanusa (Figure 1). From Libby Dam, the river flows west and then northwest into Idaho, then north into BC and Kootenay Lake. The Kootenai River at Porthill, Idaho, drains about 35,490 $km^2$. The reach in Idaho is 106 km long. Kootenay Lake drains out the West Arm, and eventually the river joins the Columbia River near Castlegar, BC.

The Kootenai River presents three different channel and habitat types as it passes through Idaho. As the river enters Idaho, steep canyon walls and a gradient of about 0.6 m/km typify the corridor. The river begins a short braided reach about 1 km below the Moyie River, then at Bonners Ferry the river transitions to a lower gradient of approximately 0.02 m/km and meanders through a broad flood plain. Tributary streams of the Kootenai River are typically high gradient as they pass through mountain canyons but revert to lower gradients when they reach the valley floor, where they have been diked.

# METHODS

## Discharge and Temperature

Daily discharge and temperature values for the Kootenai River were obtained from the USACE and the U.S. Geological Survey (USGS) office in Sandpoint, Idaho. A HOBO® or StowAway® XI temperature logger was used to monitor daily water temperatures for Smith and Boundary creeks in Idaho, Corn, and Summit creeks and the Goat River in BC, and the Kootenai River at Porthill, Idaho, from October 2000 through March 2001. At each location, mean temperature was calculated from five evenly spaced daily measurements. A temperature logger was deployed less than 50 meters upstream of each tributary creek confluence with the Kootenai River. In Summit and Boundary creeks, an additional thermograph was placed approximately 500 meters farther upstream to assess the infiltration of warmer water from the Kootenai River. These loggers assessed whether infiltration of Kootenai River water into these creek mouths was substantial, in which case the cold water inputs that burbot may use as migration cues would be obscured (Paragamian 2000). Although no burbot spawning has been documented recently, Summit and Boundary creeks are historical burbot spawning areas.

## Sampling Adult Burbot

We sampled for adult burbot from October 10, 2000 through March 22, 2001 using up to 15 baited hoop nets. Hoop nets had a maximum diameter of 0.61 m (see Paragamian 1995 for a description of the nets and the method of deployment). Nets were deployed in deep (usually the thalweg) areas of the Kootenai River between Ambush Rock (rkm 244) near Bonners Ferry, Idaho and Nick's Island (rkm 144) near Creston, BC. We also sampled three tributary streams including Deep Creek near Bonners Ferry, Idaho (rkm 240), Boundary Creek, which enters the Kootenai River at Porthill, Idaho (rkm 170), and the Goat River, near Creston, BC (rkm 152).

Nets were usually lifted on Monday, Wednesday, and Friday of each week. Fish captured in hoop nets were identified by species, enumerated, measured for total length (TL), and weighed to the nearest gram (g). Sex of most burbot was determined by a gentle massage in the vicinity of the abdomen, and the vent was examined for sex products; some post-spawn fish were biopsied for a visual inspection. All burbot were implanted with a passive integrated transponder (PIT) tag in the left opercular muscle, and a small piece of pelvic fin tissue was collected for genetic analysis and archiving (Paragamian 1999). Relative weight ($W_r$; Fisher et al. 1996) was calculated for each burbot captured.

To estimate abundance of spawning burbot at Ambush Rock, we used a Lincoln-Petersen and a Schnabel estimator (Van Den Avyle 1993). Both models assume that: 1) no tags are lost, 2) that there are no additions or losses to the population, 3) that marked fish are all correctly identified and marked, and that 4) unmarked fish are equally likely to be recaptured, have equal mortality rates, and randomly mix after release.

## Burbot Telemetry

Sonic transmitters were used to track adult burbot movement throughout the year. Sonic transmitters had a 420 d life expectancy, were cylindrical in shape, measured 18 mm by 65 mm, and weighed 8 g. Sonic transmitters were surgically implanted (see Paragamian 1995 for a description of the surgical procedures). When possible, sex of each burbot was determined during surgery. Sonic telemetry was conducted from a boat primarily on alternate days of net lifting and occasionally on the same day as net lifts. When burbot were located by telemetry, the location was recorded to the nearest 0.1 rkm.

## Blood Collection and Analysis

We collected blood from anesthetized burbot using a 25 mm, 20-gauge needle and a 10 ml, heparinized vacuum tube (Strange 1983). Each fish was placed in a cradle with its ventral side up, and we inserted a sterile needle 5 mm posterior of the anus along the midline. After insertion, the needle was slowly pushed until it reached the vertebral column, and then the vacuum tube was punctured with the opposite end of the needle. If blood did not flow into the tube immediately, the needle was either moved laterally or additional downward pressure was applied until 1-4 ml of blood was collected. Blood was stored in a cooler on ice or snow. As soon as possible, usually within 4 to 6 hours of collection, blood was centrifuged for 5 minutes at 5,000 X gravity. Serum was removed with a pipette, placed in a sterile plastic container, and frozen at –20°C.

All samples were extracted with anhydrous ether to purify the steroids from any binding proteins in the plasma and analyzed in duplicate using radioimmunology assay (RIA) by personnel at the Oregon Cooperative Fishery Research Unit at Oregon State University (Beth Siddens, Oregon State University, personal communication). Levels of testosterone (T), estradiol-17ß ($E_2$), and 11-ketotestosterone (11-KT) were measured and are expressed as ng/ml. Steroid levels below 0.30 ng/ml for T, 0.87 ng/ml for 11-KT, and 0.34 ng/ml for $E_2$ were below the lowest standard in the assays, also known as the lower limit of detection (LLD), and therefore were not detected.

## Larval Sampling

Larval burbot sampling was conducted using paired ½ m nets (mouth area = 0.7854 $m^2$) from March 15 through May 2, 2001 in the Kootenai River with a boat 8 m in length. One net was towed at the surface, while the other sampled at approximately 1.5 m of depth below the surface. Gurley 2030 R current meters were mounted in the mouth of each net, and tows were made in a downstream direction; the boat motor (150 hp) was operated at 1,000 rpm to maintain uniform towing speed. Tows were made at mid channel in the vicinity of Ambush Rock (rkm 247) because of shallow water and debris near the river margin. Tows downstream to the mouth of the Kootenai River (rkm 124.7) were conducted near the shoreline. Effort was calculated using total towing time and rotation counts per second from the flow meters x mouth area (0.7854 $m^2$) to calculate the total volume of water filtered through each net.

# RESULTS

## Discharge and Temperature

### Kootenai River Discharge

Discharge of the Kootenai River at Libby Dam was stable at 170 $m^3$/s from October 1 through November 6, 2000 (Figure 3). Discharge doubled by November 9, 2000 and remained at 340 m$^3$/s until November 17, 2000. During the following three weeks, discharge fluctuated between 170 and 340 m$^3$/s. On December 10, 2000, discharge increased rapidly and by the following day reached the winter maximum (592 m$^3$/s). Discharge, for the most part, decreased throughout December to 170 m$^3$/s by December 23 and to the winter minimum (113 m$^3$/s) on January 1, 2000. Discharge remained at 113 m$^3$/s for the first 20 d of January. On January 21, 2001, discharge increased and plateaued at 283 m$^3$/s for 15 d. Afterwards, discharge increased again to 425 m$^3$/s and remained at this level from February 8 to 18, 2001. Discharge decreased during late February and early March and did not exceed 128 m$^3$/s from March 6 to 31, 2001.

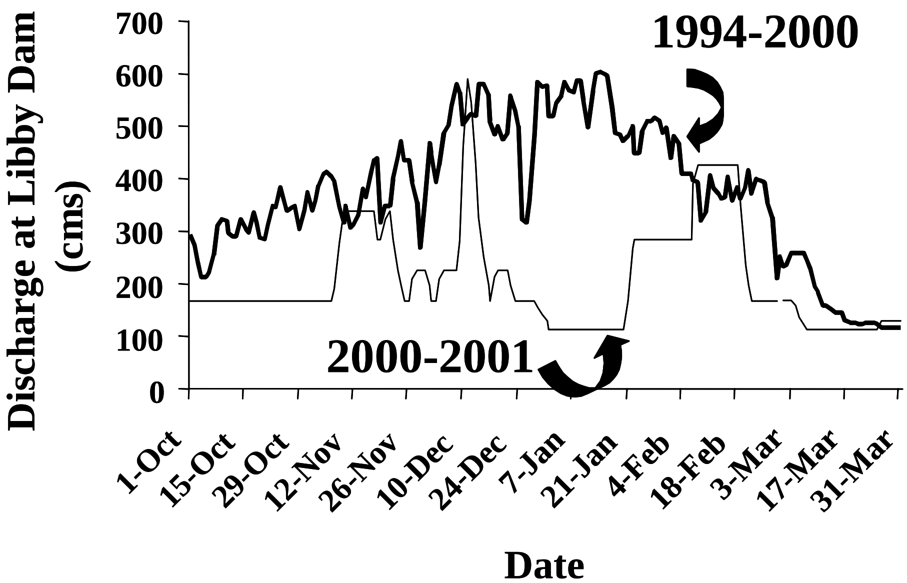


Figure 3. Kootenai River discharge at Libby Dam from October 1, 2000 through March 31, 2001 and the average for 1994-2000.

## Kootenai River Temperature

Mean daily water temperature for the Kootenai River at Porthill from October 20, 2000 to March 5, 2001 averaged 4.46°C and ranged from a maximum of 10.87°C for October 20, 2000 to a minimum of 0.01°C for January 21, 2001 (Figure 4).

## Tributary Temperatures

Temperatures of five tributaries of the Kootenai River in Idaho and BC, Canada were monitored from October 20, 2000 through March 5, 2001. Mean water temperature of Smith Creek was 1.94°C (Figure 5). The maximum temperature of 6.61°C occurred on October 20, 2000, whereas the minimum temperature of –0.06°C occurred on January 9, 2001. At the upstream site in Boundary Creek, mean water temperature was 0.85°C with a maximum of 7.02°C on October 10 and a minimum of -0.05°C on December 28 (Figure 6). In lower Boundary Creek, mean water temperature at the mouth was 1.89°C and ranged from a maximum of 7.45°C on October 20, 2000 to a minimum of 0.14°C on January 26, 2001 (Figure 7).

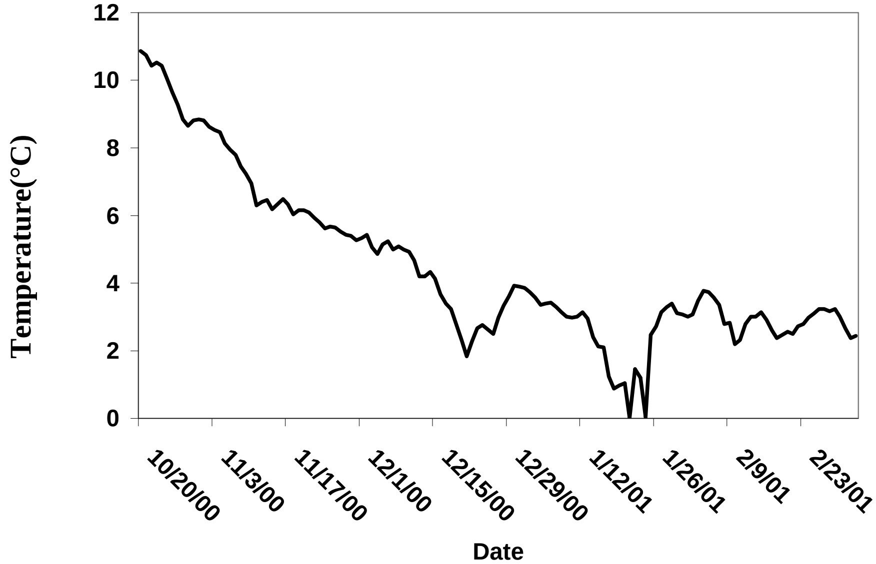


Figure 4. Mean daily temperature (°C) of the Kootenai River at Porthill from October 20, 2000 through March 5, 2001.

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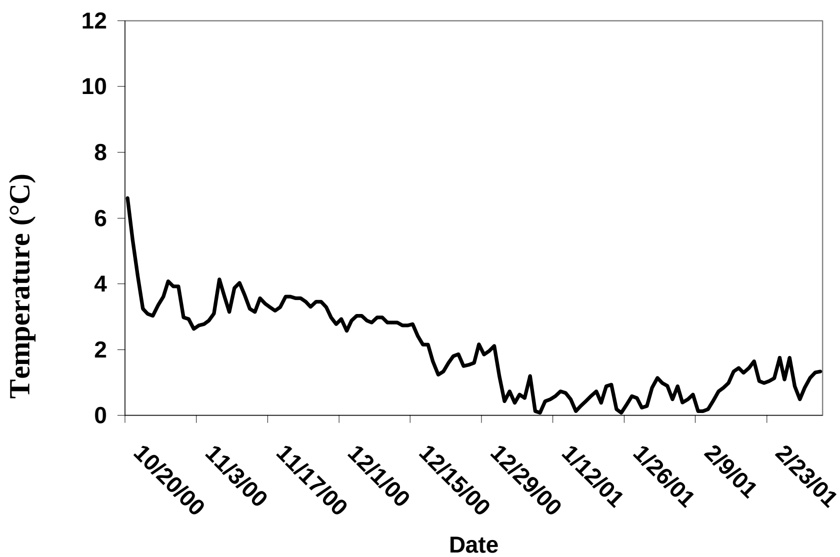


Figure 5. Mean daily temperature (°C) of Smith Creek from October 20, 2000 through March 5, 2001.

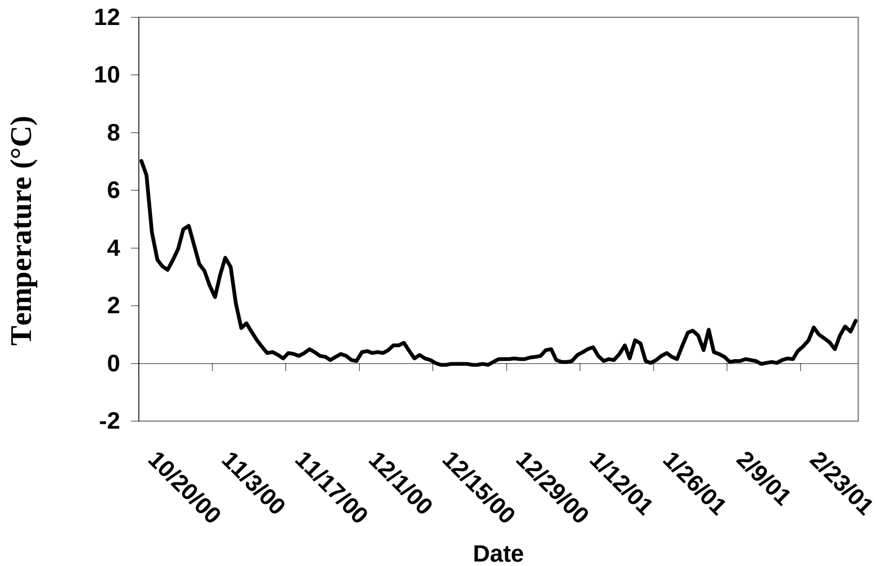


Figure 6. Mean daily temperature (°C) of upper Boundary Creek from October 20, 2000 through March 5, 2001.

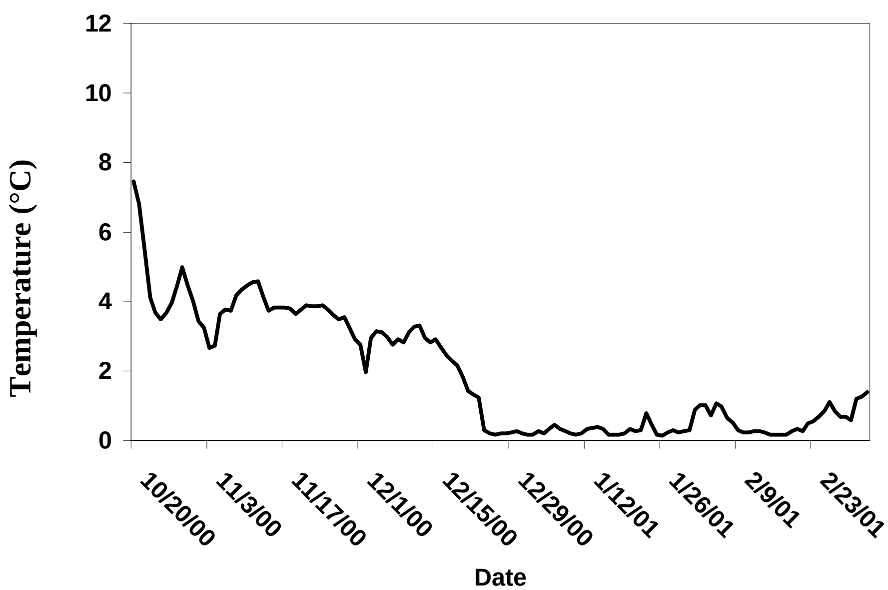


Figure 7. Mean daily temperature (°C) of lower Boundary Creek from October 20, 2000 through March 5, 2001.

Mean water temperature of the Goat River over the same period was 1.87°C (Figure 8). The maximum temperature of 8.07°C occurred on October 20, 2000, whereas the minimum temperature of 0.48°C occurred on December 18 and 24, 2000. Mean water temperature of Corn Creek over the same period was 1.32°C (Figure 9). The maximum temperature of about 9.5°C occurred on October 10, 2000, whereas the minimum temperature of 0.14°C occurred on January 26, 2001. In Summit Creek, mean water temperature at the upstream site was 0.61°C with a maximum of 6.61°C and a minimum of -0.01°C during late November and most of December (Figure 10). At the mouth of Summit Creek, mean daily water temperature was 1.41°C and ranged from a maximum of 6.85°C during October to a minimum of 0.01°C on January 25, 2001 (Figure 11).

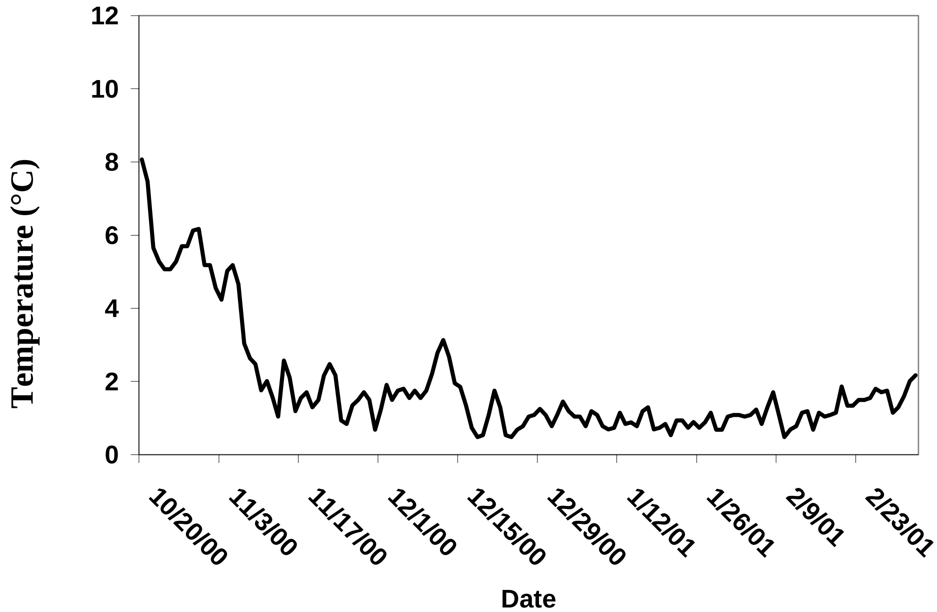


Figure 8. Mean daily temperature (°C) of the Goat River from October 20, 2000 through March 5, 2001.

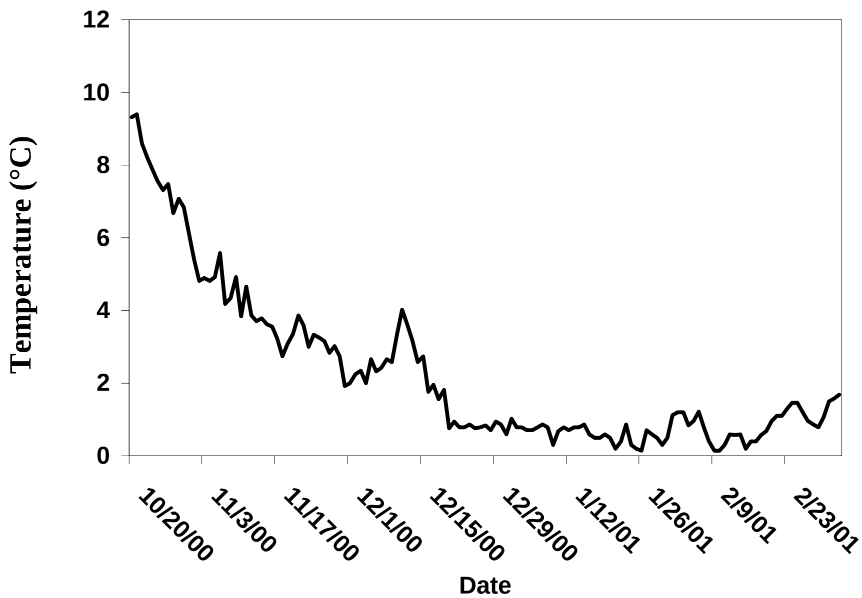


Figure 9. Mean daily temperature (°C) of Corn Creek from October 20, 2000 through March 5, 2001.

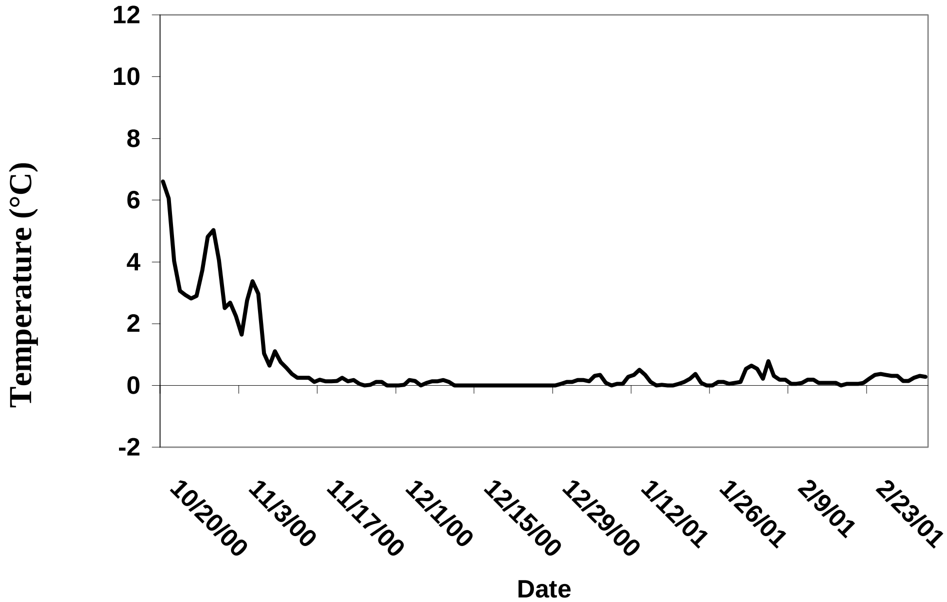


Figure 10. Mean daily temperature (°C) of upper Summit Creek from October 20, 2000 through March 5, 2001.

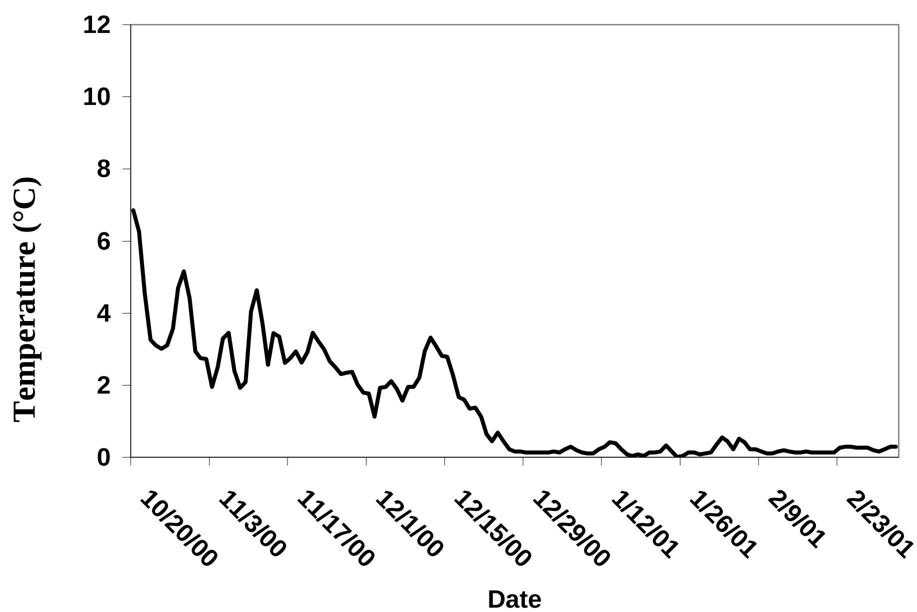


Figure 11. Mean daily temperature (°C) of lower Summit Creek from October 20, 2000 through March 5, 2001.

The mean difference from October 20, 2000 to March 5, 2001 in mean temperature between the mouth and the upstream location in Boundary and Summit creeks was 1.04°C and 0.8°C, respectively. The daily difference in mean temperature was quite substantial during November and December, when temperatures at the mouths of both creeks were 3-4°C warmer than at upstream locations (Figure 12 and 13). By late December, the mean difference between upper and lower sites in each creek approached zero, when the surface elevation of the Kootenai River dropped and warmer river water drained from the tributary mouths.

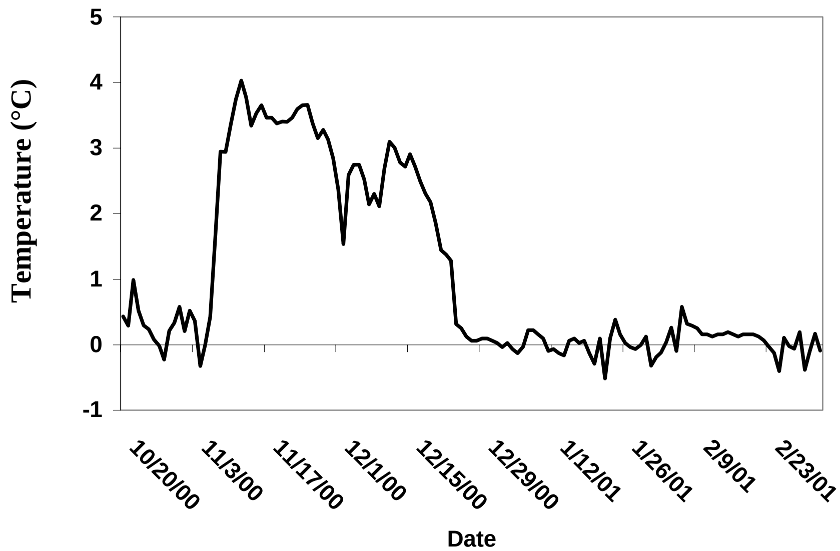


Figure 12. Difference in mean daily temperature (°C) between lower and upper Boundary Creek from October 20, 2000 through March 5, 2001.

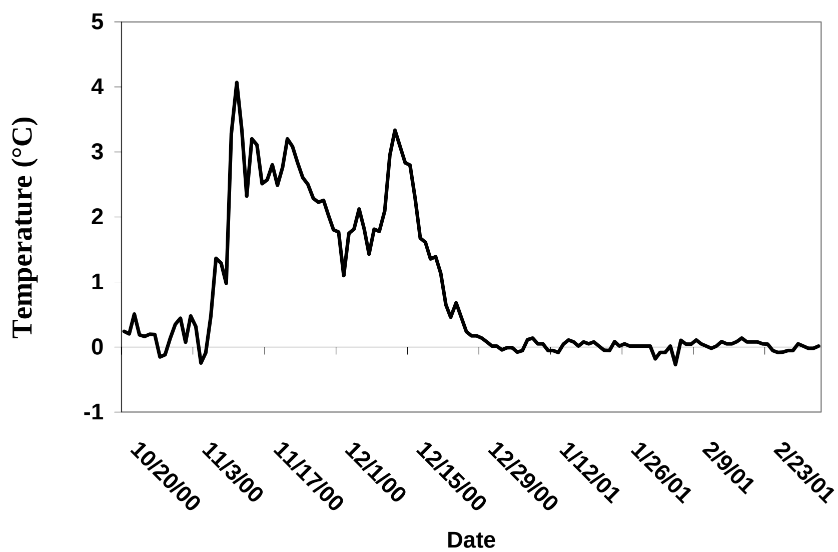


Figure 13. Difference in mean daily temperature (°C) between lower and upper Summit Creek from October 20, 2000 through March 5, 2001.

## Sampling Adult Burbot

### Total Catch

We fished baited hoop nets from October 10, 2000 to March 22, 2001 for 51,190 h or 2,133 net d. A total of 229 fish was caught including 12 different species of fish, one hybrid, and 28 crayfish (Table 1). Catch per unit of effort was 0.107 fish/net d for all species of fish (crayfish excluded) and 0.034 fish/net d for burbot or one burbot captured every 29.2 net d (Table 1).

### Hoop Net Catch of Burbot

Overall, we made 73 burbot captures in Idaho and BC (Table 1, Figure 14). Of the 59 burbot captures in Idaho, 52 occurred at Ambush Rock. A large majority of the captures (44) at Ambush Rock occurred in a 19 d period from January 26 to February 13, 2001, including captures of 16 fish in one net on two separate occasions, February 6 and 13, 2001.

In BC, 14 burbot captures occurred, including seven captures in the Kootenai River from rkm 150 to 156 and seven captures in the Goat River. The seven captures in the Goat River all occurred in one net on February 8, 2001.

We obtained length and weight measurements from 39 burbot (fish repeatedly captured over a short time period were excluded). Burbot ranged from 400 mm to 753 mm TL (mean = 576 mm, SE = 10.45) (Figure 14) and weighed from 400 g to 2,700 g (mean = 1,343 g, SE = 75.31). Relative weight ($W_r$) ranged from 67 to 140 and averaged 95 (SE = 1.94).

Of the 73 burbot captures that occurred during 2000-2001, 34 (47%) were recaptures marked during previous sampling events or were caught multiple times during the winter of 2000-2001. Twenty individual burbot comprised these recaptures, including 13 fish recaptured one time, four fish recaptured twice, one fish recaptured three times, and two fish recaptured five times. The sex ratio of male:female:unknown (examined but sex could not be differentiated) burbot was 0.6:0.15:0.25.

Nine of the 20 burbot recaptured from October 10, 2000 through March 22, 2001 were initially caught at Ambush Rock during February 2001 and recaptured once later in the month at the same location (Appendix 1). Three others were initially captured at Ambush Rock and recaptured two more times, mostly at Ambush Rock (Fish #218, 225, and 227).

Six burbot were initially caught in Idaho during previous winters and then recaptured in Idaho this winter. Two male burbot (Fish #211 and 212) initially caught at Ambush Rock on March 10, 2000 were recaptured five times each at the same location from October 16, 2000 through February 13, 2001. This pattern was similar in two other male burbot (Fish #209, 214) that had the same date and location of initial capture but fewer recaptures. Fish #186, a male burbot, was initially captured on October 29, 1999 at rkm 207, recaptured twice at Ambush Rock in March 2000, and recaptured two more times at Ambush Rock the following winter. Fish #180, a male burbot, was initially captured on March 13, 1999 at Ambush Rock and recaptured twice almost two years later.

Table 1. Hoop net catch by number, weight (kg), and catch per unit effort (CPUE) for the Kootenai River and its tributaries in Idaho and BC, October 10, 2000 through March 22, 2001.

| **Species** | **Number** | **Total Weight (kg)** | **CPUE[a]** |
|---|---|---|---|
| Northern pikeminnow | | | |
| *Ptychocheilus oregonensis* | 74 | 36.65 | 0.0347 |
| Burbot | | | |
| | 73 | 104.96 | 0.0342 |
| Crayfish | | | |
| *Pasifastacus spp.* | 28 | NA | 0.0131 |
| Sucker[d] | | | |
| *Catostomus catostomus* | | | |
| and *C. macrocheilus* | 23 | 5.61 | 0.0108 |
| Peamouth chub | | | |
| *Mylocheilus caurinus* | 20 | 3.05 | 0.0094 |
| White sturgeon | | | |
| *Acipenser transmontanus* | 11 | 2.11 | 0.0052 |
| Bull trout | | | |
| *Salvelinus confluentus* | 10 | 13.19[c] | 0.0047 |
| Yellow perch | | | |
| *Perca flavescens* | 8 | 0.66 | 0.0038 |
| Black bullhead | | | |
| *Ameiurus spp.* | 3 | 0.19 | 0.0014 |
| Mountain whitefish | | | |
| *Prosopium williamsoni* | 3 | 0.45 | 0.0014 |
| Rainbow trout | | | |
| *Oncorhynchus mykiss* | 2 | 0.81 | 0.0009 |
| Westslope cutthroat trout | | | |
| *Oncorhynchus clarki lewisi* | 1 | 0.40 | 0.0005 |
| Cuttbow trout | | | |
| *Oncorhynchus clarki lewisi x mykiss* | 1 | 0.45 | 0.0005 |
| **Total** | **229[b]** | **168.53[b,c]** | **0.1074[b]** |

[a] A unit of effort is a single net set for 24 hours.
[b] Crayfish excluded from total.
[c] One of the ten bull trout was not weighed.
[d] Includes longnose and largescale sucker.

The remaining two fish captured in multiple winters were initially captured in BC. Fish #205 was captured in the Goat River on February 18, 2000 and was recaptured at the same location just less than a year later on February 8, 2000. Fish #196 was initially captured at rkm 151.9, downstream of the Goat River, on January 5, 2000 but was recaptured in Idaho at rkm 220.5 on October 30, 2000.

For the Lincoln-Petersen and Schnabel population estimation of spawners at Ambush Rock, the 16 fish captured on February 6, 2001 were used as the initial mark and release group, whereas the 16 fish recaptured on February 13, 2001 were the final group examined for marks. In addition for the Schnabel estimator, the four fish captured on February 9, 2001 were examined for marks, marked if no tag was present, and released. The Lincoln-Petersen estimate of the number of spawners at Ambush Rock was 26 fish with a 95% confidence interval of 19-41. The Schnabel estimate of the number of spawners at Ambush Rock was 24 fish with a 95% confidence interval of 16-50. We used the mark and recapture of burbot from October 2000 through March 2001 in a Seber-Jolly-Cormack population estimator that included mark and recaptures from 1994-2000, but the resulting variance was so high that it did not provide a valid estimate of total population size.

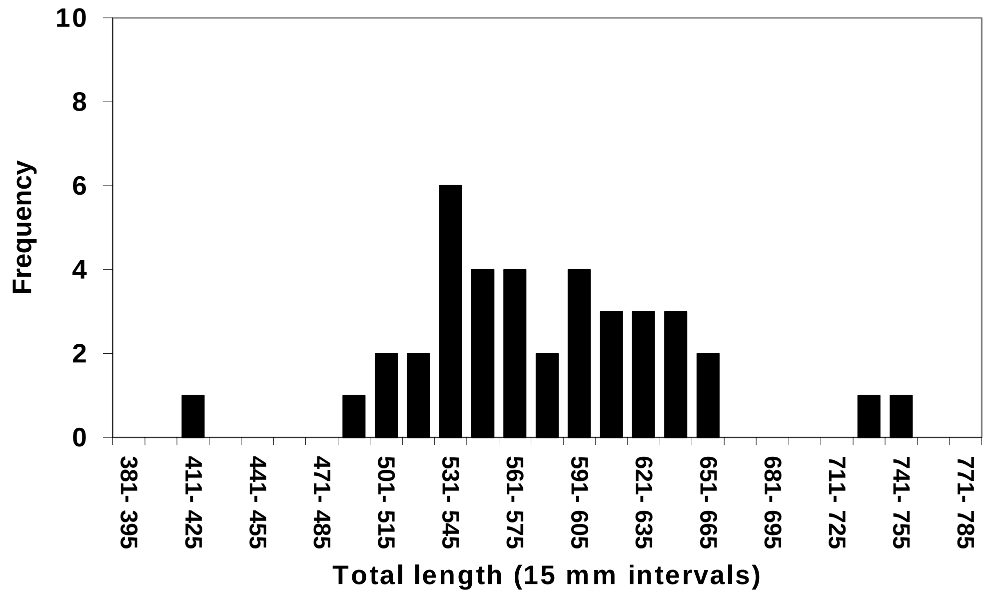


Figure 14. Length frequency distribution of burbot caught by baited hoop nets, excluding recaptures, in the Kootenai River and its tributaries in Idaho and BC, from October 10, 2000 through March 22, 2001.

## Burbot Telemetry

Ten burbot were surgically implanted with sonic transmitters from January 26 through February 6, 2001 (Table 2), including five fish tagged and released at Ambush Rock (rkm 245), one fish near the mouth of Boundary Creek (rkm 170), and four fish near the mouth of the Goat River (rkm 152.7). Five burbot were females, three were males, and two were unidentifiable. Sonic-tagged burbot ranged in length from 500 to 745 mm and weighed from 975 to 2,175 g.

We spent 89.6 hours tracking burbot from rkm 132 to 245 during February and March 2001. During this time period, we made 88 locations of burbot. We were unable to monitor upstream, prespawn movements, because our captures of burbot in BC for telemetry purposes were very low from November 2000 through January 2001. Instead, all fish that we tracked were captured immediately prior to or during the spawning period. Therefore, our telemetry data is representative only of time spent at spawning locations and of post-spawn migrations (Appendices 2 through 21). In addition, our request for a low-flow test period was dismissed by the USACE because the Kootenai River Basin was at about 50% of normal snow pack and the region was in a drought (by April 2001 the snow pack was estimated at 65% of normal).

During February and March, six of the 10 tracked burbot moved less than 5 km. Three of these fish (Fish #211, 230, and 233) moved less than 2 km from their original tagging and release location (Appendices 12, 16, and 19). Two other burbot (Fish #227 and 240) remained at Ambush Rock for approximately a week after tagging and then moved slowly downstream to near Deep Creek (rkm 240; Appendices 15 and 21). Conversely, one burbot (Fish #232) tagged in the Goat River left this tributary and moved as much as 1 km up the Kootenai River, only to return to the Goat River (Appendix 18). On February 22, 2001, we were able to locate this fish with sonic equipment and then visually in the Goat River approximately 0.7 km from the mouth of the Kootenai River, where it was positioned on the sand substrate of a 4.3 m deep pool. By March 8, 2001, this fish had left the Goat River for at least the second time and was found 3 km upstream of the mouth of the Goat River in the Kootenai River.

The remaining four burbot moved more than 5 km during February and March. Two of these fish (Fish #218 and 226) tagged at Ambush Rock in late January made relatively large-scale downstream movements to rkm 207 and 208 by February 26, 2001 (Appendices 13 and 14). Fish #234 remained within 2 km of the Goat River after being tagged there. Afterwards, this fish moved over 12 km downstream to rkm 140 and by March 8, 2001 had moved back upstream to rkm 147 (Appendix 20). Burbot #231 followed the same pattern as Fish #234 and remained within 0.5 km of the Goat River for 10 days after being tagged and released, then moved 8.7 km downstream to rkm 144 February 13, 2001 (Appendix 17).

From April 25 through May 3, 2001, we conducted consistent surveys of the river from rkm 245 through 120 and found eight active tags (Fish #231 and 240 were not located) (Appendices 17 and 21). Fish #218 and 226 continued their steady downstream movement patterns (Appendices 13 and 14). Fish #230 and 233 moved upstream, with the latter moving 28.7 km upstream since we last located it on February 22, 2001 (Appendices 16 and 19). Fish #211, 227, and 234 showed no noticeable movement from earlier locations (12, 15, and 20). Fish #232 made upstream and downstream movements (Appendix 18) but remained within a relatively small area (rkm 155.2-155.6).

Final telemetry locations for the season for individual fish were completed during July, August, and September 2001. Five of the 10 tagged burbot were relocated: #211, 226, 227, 230, and 234 (Appendices 12, 14, 15, 16, and 20). Burbot #234 and 230 had moved very little since May, while #211, 227, and 226 had moved 8, 19.5, and 7.5 km, respectively.

## Blood Collection and Analysis

From January 26 through March 9, 2001, we collected 22 blood samples, including 18 samples from burbot located at Ambush Rock, three samples from the Goat River, and one sample from the mouth of Deep Creek (Appendix 22). Blood was sampled from 15 male burbot and two female burbot. Five samples were collected from burbot of unknown sex. On February 14, 2001, we collected an additional 17 blood samples from burbot captured with a weir in an unnamed tributary of Columbia Lake, BC, including nine fish positively identified as males, three as females, and five fish of unknown sex (Appendix 23).

**Male Burbot**

T levels in Kootenai River male burbot showed a linear decrease from January 26 through February 13, 2001 (Figure 15), when mean daily T levels dropped from 22.03 ng/ml (n = 4) to 1.32 ng/ml (n = 3). In Columbia Lake males sampled on February 14, 2001, mean level of T was slightly lower (0.66 ng/ml; n = 7) than in Kootenai River males sampled the previous day. Levels of 11-KT followed a similar trend with a linear decrease from January 26 through February 13, 2001 (Figure 16). During this time period, mean levels of 11-KT decreased from 41.0 ng/ml (n = 4) to less than 2.12 ng/ml (n = 3). The levels of 11-KT in Columbia Lake males sampled on February 14, 2001 were also low. Five of the seven samples measured below the LLD, and the other two averaged 5.03 ng/ml. $E_2$ levels were low for all male burbot sampled and showed no temporal trend.

Table 2. Summary of telemetry data and physical characteristics of 10 burbot in the Kootenai River, Idaho and BC, Canada, January 2000 through September 2001.

| Sonic Code | Fish Number | Pit Tag Number | Release Site (rkm) | Release Date | Depth (m) | Total Length (mm) | Weight (g) | Sex | Last Date Located |
|---|---|---|---|---|---|---|---|---|---|
| 2239 | 211 | 7F7D434A22 | 244.6 | 01/29/01 | 20.4 | 650 | 1725 | M | 07/19/01 |
| 325 | 218 | 7F7D041608 | 244.6 | 01/29/01 | 15.8 | 568 | 1400 | F | 06/18/01 |
| 3334 | 226 | 7F7F427956 | 244.6 | 01/29/01 | 20.4 | 547 | 1100 | — | 09/13/01 |
| 583 | 227 | 7F7D04312F | 244.5 | 02/06/01 | 20.1 | 745 | 2175 | F | 09/11/01 |
| 2228 | 230 | 7F7D0F066A | 170 | 01/30/01 | 19.2 | 578 | 1200 | M | 09/13/01 |
| 2259 | 231 | 7F7D042260 | 152.7 | 01/30/01 | 13.1 | 614 | 1450 | F | 02/13/01 |
| 2249 | 232 | 7F7D424630 | 152.7 | 02/02/01 | 11.9 | 500 | 975 | — | 05/03/01 |
| 357 | 233 | 7F7F3F6161 | 150.9 | 02/05/01 | 18.6 | 605 | 1500 | F | 06/07/01 |
| 2632 | 234 | 7F7D374B5A | 152.7 | 02/05/01 | 2.4 | 561 | 1100 | F | 09/18/01 |
| 3344 | 240 | 7F7D41332E | 244.5 | 02/06/01 | 20.1 | 612 | 1390 | M | 03/22/01 |

**Females and Unknown Sex Burbot**

In the Kootenai River and Columbia Lake, levels of T and 11-KT for four of the five female burbot captured were less than 2.1 ng/ml and often below LLD (Appendix 22). The only exception was one female captured on January 26, 2001 that had T and 11-KT levels of 15.15 and 3.46 ng/ml, respectively. Similarly, levels of T and 11-KT were low for all burbot of unknown sex, except for one individual captured in the Kootenai River on February 13, 2001. As in males, levels of $E_2$ were low (less than 0.65 ng/ml) in female and unknown sex burbot.

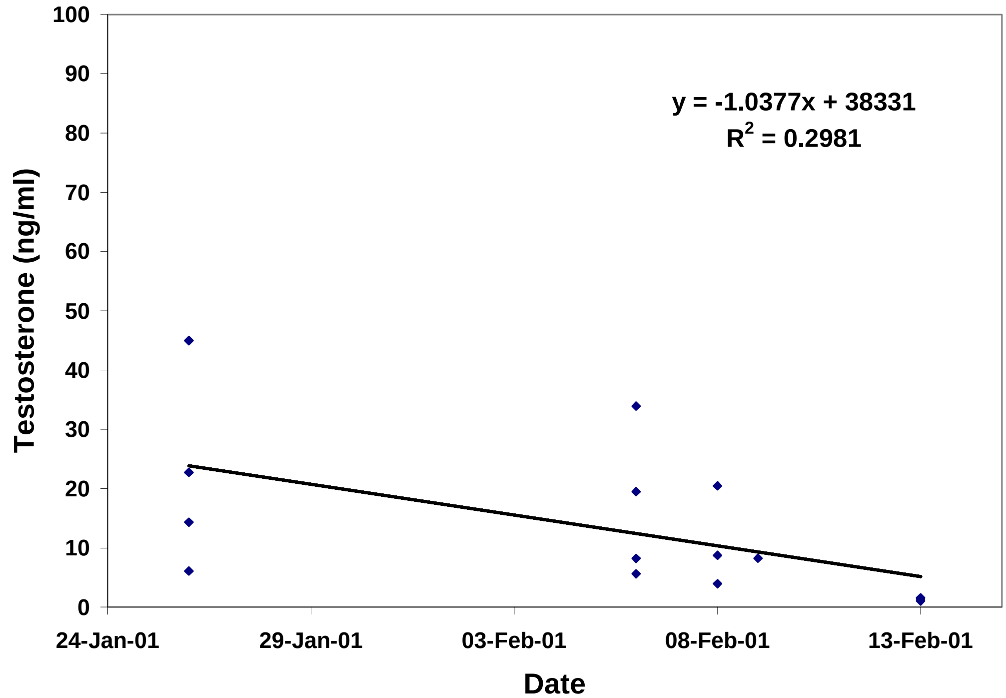


Figure 15. Testosterone levels of 15 male burbot captured in the Kootenai River from January 26 through February 13, 2001.

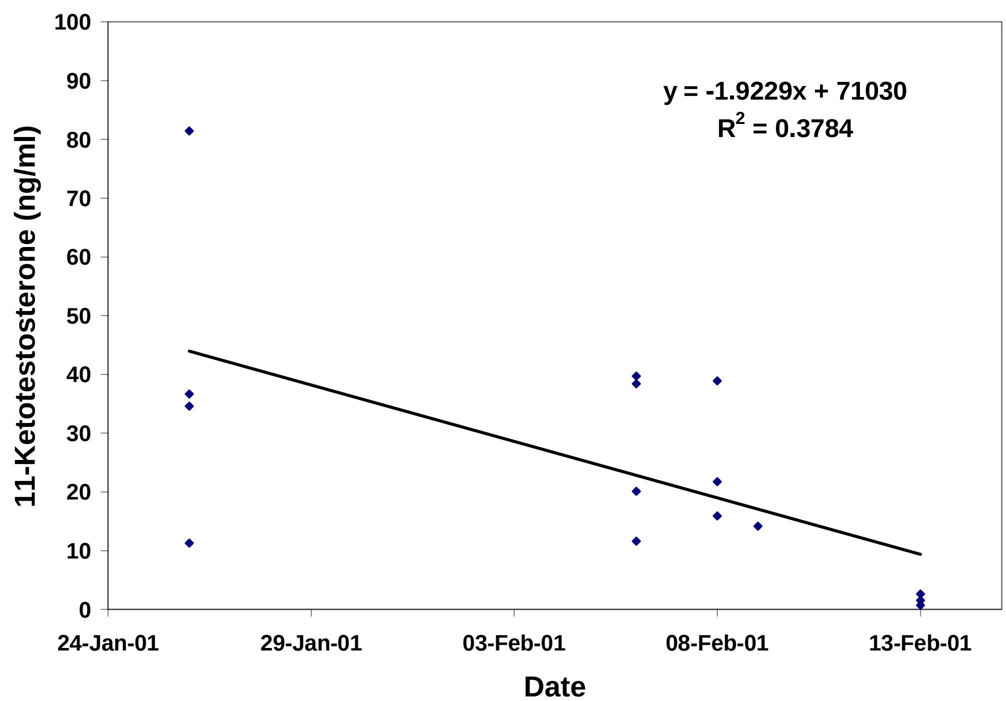


Figure 16. 11-Ketotestosterone levels of 15 male burbot captured in Idaho from January 26 through February 13, 2001.

## Larval Sampling

Sampling for larval burbot was conducted from March 15 through May 2, 2001 in the Kootenai River from rkm 247.0 through 124.7. A total of 78 paired ½ meter net tows were made, averaging approximately 20 minutes each. Total towing time was 25 hours, 34 minutes, and 39 seconds. The nets filtered a total water volume of 91,803 $m^3$. No larval burbot were captured.

# DISCUSSION

The operation of Libby Dam during winter for hydropower production and flood control has been cited as one of the major factors contributing to the decline of burbot in the Kootenai River (Paragamian 2000). Comparisons of two decades of winter flow data have revealed that after dam construction, peak flows have tripled and are more variable (Figure 2). Due to low precipitation and snow pack estimated at times at less than 50 percent of normal, as well as low reservoir levels in Lake Koocanusa, the USACE refrained from releasing more than a minimum flow of 113 $m^3/s$ from Libby Dam for most of the 2000-2001 winter. Presumably, these factors allowed burbot to develop and behave much like they did prior to the construction and operation of Libby Dam. The result in reality was a low flow test that allowed for investigation of burbot spawning migration. The results served to confirm our previous findings that in the absence of high flows, burbot distributed themselves more extensively during the spawning period and are believed to have spawned (Paragamian 2000).

Our total number of captures of 73 burbot in 2000-2001 was from one and a half to four times greater than the previous eight winters. Although increased effort may have contributed slightly to our higher catch, few fish were captured in our additional nets. We continued to catch burbot in only a few distinct areas, including Ambush Rock, Idaho as well as in and near the Goat River, BC. In fact, over half of the burbot captures occurred at Ambush Rock during late January and the first two weeks of February. During this period, both male and female burbot were identified as gravid, flowing, or spent. These fish represent the largest known spawning congregation of Kootenai River burbot in Idaho within the last decade. In addition, our highest catches of burbot in the Goat River occurred during this same time period, and gravid fish were identified.

Despite the higher catches observed during this study, there is no evidence to indicate that the burbot population in Idaho has increased, considering that estimates of the number of spawners at Ambush Rock were less than 30 fish. Mark and recapture estimators, such as the Lincoln-Petersen and Schnabel, are often used to estimate fish population size in closed systems provided several assumptions are met. Our estimate may be slightly biased if we violated the assumptions of a closed population or equal probability of capture. No physical barrier existed to prevent fish from entering or leaving Ambush Rock from the time we initially marked fish to our final recapture effort. However, several lines of evidence indicate that few burbot left the spawning area. Several nets downstream of Ambush Rock caught no burbot, and none of our sonic-tagged fish located at Ambush Rock left the area during the spawning period (last week in January to first week in February). Furthermore, burbot are group spawners and release eggs and milt in large writhing balls containing several individuals (McPhail and Paragamian 2000). After spawning, burbot may remain in spawning areas for up to several weeks (Arndt and Hutchinson 2000). In contrast, it is probable that we violated the equal probability of capture assumption, and this may have biased our estimates. There is no information available regarding how burbot locate each other for spawning, but when one or more females entered our nets, up to several males were also captured. On two occasions a single net captured 16 burbot. This tendency caused us to have a higher recapture rate on males and may have caused us to underestimate the true spawning population size.

Catch per unit effort (CPUE) has been used to compare burbot stock densities (Parker et al. 1988). Burbot densities vary between river and lake environments, but CPUE in the Kootenai River for winter sampling is very low, ranging from one fish/18 net d to one fish/45 net d (Paragamian 2000). During the winter of 2000-2001, CPUE was within this range at one fish/29.2 net d. For comparison, CPUE of burbot in four Alaskan Lakes ranged from one fish/two net d to three fish/one net d (Parker et al. 1988), while in the Tanana and Chena rivers CPUE was >one fish/one net d and one fish/two net d, respectively (Evenson 1993). Based on these comparisons, the densities of burbot in exploited Alaskan fisheries appear to be 20 times greater, at a minimum, than the Kootenai River population.

Burbot are known to have low swimming endurance (Jones et al. 1974), but are capable of making long distance migrations in rivers during low flow periods (Bresser et al. 1988). During the post-spawn period of 2000-2001, tagged burbot exhibited downstream, sedentary, and upstream movement patterns. It is doubtful that the sustained, unidirectional downstream movement we saw in two burbot was an artifact of our surgical procedures, but the stress of inserting tags may have caused other fish to move downstream and recover before resuming normal movement patterns. Downstream movement for repeat-spawning, potadramous burbot occurs in some systems when tributaries become too warm during summer. This behavior has been documented in Columbia Lake, BC (Arndt and Hutchinson 2000) and Lake Superior, Wisconsin (Schram 2000). In telemetry studies, it is often difficult to differentiate between tag loss or fish death and limited movement unless a fish makes an upstream or lateral movement. In this study, nine of ten burbot made at least one short upstream movement, occupied relatively small areas, and remained there for one or more months. Presumably, burbot may occupy small localized areas across long time periods if adequate food and water temperatures are available. Three of 21 burbot tagged in the Tanana River, Alaska moved less than 5 rkm over a ten month period (Bresser et al. 1988), and burbot in Lake Opeongo, Ontario remained in small localized areas during spring and summer (Carl 1995). Post-spawn upstream movements in burbot are rare but do exist in at least one fluvial population. In tributaries of the Susquehanna River, New York, adult burbot moved upstream after spawning to colder headwater areas when mainstem water temperatures rose from mid-March to early May (Robins and Deubler 1955). The post-spawn upstream movement that we observed in the Kootenai River may have been a delayed spawning migration caused by the stress of inserting a sonic tag or a post-spawn movement to more suitable riverine habitats. In past years, few fish have moved upstream during the post-spawn period when river flows and the energetic cost of migrating upstream were high (Paragamian and Whitman 1996, 1997).

The capture of unspawned females (reabsorbing eggs) and unspent males during the post-spawn season has been common in the Idaho reach of the Kootenai River in previous years (Paragamian and Whitman 1996 and 1997). We believe high fluctuating flows from Libby Dam have continuously disrupted burbot migrations (Paragamian 2000) and may be responsible for the failure of spawning. The specific effect of this disruption to burbot spawning is unknown, but it may have reduced spawning fitness, timing of spawning synchrony, or both. It may also have influenced vitellogenin synthesis, and stress may contribute to ovulation failure or reduced stamina. One or all of these factors could have been sufficient to prevent spawning success and recruitment necessary to sustain the fishery. However, during the post-spawn period of 2001 for the first time since this study began in 1993, recaptured females and males showed circumstantial evidence of spawning: weight loss of prespawn gravid females of several hundred grams and spent testes in post-spawn males.

Although flows were relatively low during the winter of 2000-2001 in comparison to previous post-Libby Dam years (Figure 3), there were several rapid increases in flow for brief periods of time that did not appear to affect burbot once their spawning groups were established. The highest flow occurred on December 10, 2000, when flow increased rapidly from about 170 to 592 $m^3$/s. Discharge decreased rapidly to about 113 $m^3$/s, but during the spawning period it increased again and plateaued at 283 $m^3$/s for 15 d and increased again to 425 $m^3$/s. During this period we did not notice any significant movement of burbot with transmitters in the Ambush Rock area.

The sharp drop of plasma testosterone and 11-KT observed in male burbot during this study immediately prior to spawning is common in other teleosts. Levels of T and 11-KT in male pink salmon *Oncorhynchus gorbuscha* dropped between arrival at spawning locations until fish were spent by 30 and 45 ng/ml, respectively (Dye et al. 1986). During April, level of T in male walleye dropped from 2 to less than 0.5 ng/ml, while 11-KT dropped from approximately 35 to 5 ng/ml (Malison et al. 1994). Although we were unable to compare prespawn values to post-spawn values, levels of testosterone in post-spawn, Columbia Lake male burbot were similar to post-spawn values for the Kootenai River burbot. These results further substantiate that under the low flow conditions prevalent in 2000-2001, male burbot were able to mature, migrate, and spawn. Although we believe we were able to observe normal development and timing of spawning in females in the Kootenai River, we were only able to collect a few blood samples from this population and our control population from Columbia Lake. Our data showed no trend in levels of T or 11-KT. Levels of estradiol were low in all female fish from both systems.

Estradiol stimulates synthesis of vitellogenin, which is necessary for final egg maturation. By not collecting blood from female burbot until late January immediately prior to spawning, we may have missed the decline in estradiol that occurs in other teleosts. In female pink salmon, levels of estradiol dropped approximately 10 days before levels of testosterone and 11-KT dropped in males arriving at spawning locations (Dye et al. 1986). In female walleye sampled from the Mississippi River, Minnesota, estradiol levels peaked in November at 3.7 ng/ml and decreased to less than 0.5 ng/ml by the spawning season in April (Malison et al. 1994). In future years, additional blood samples from female burbot, especially during November and December, should be collected to determine whether estradiol levels peak prior to spawning and then decline. In summation, we did not observe elevated levels of estradiol in female burbot or elevated levels of T or 11-KT in male burbot well after the spawning season that would have indicated reproductive dysfunction.

## RECOMMENDATIONS

1. We recommend a three-week test flow of 170 $m^3$/s beginning December 1, 2000 through December 23, 2000 to test the null hypothesis that burbot migration distance or travel rate (distance/day) during the normal operation control treatment (hydropower production and floodwater evacuation) is not different than a low flow test treatment.

2. Monitor physiological condition of burbot during and after spawning. Document whether or not burbot spawned and monitor blood chemistry to determine the level of testosterone, 11-KT, and 17β estradiol. .

3. Determine, under laboratory conditions, the effect of high velocities (>25 cm/s) and elevated winter temperatures on vitellogenin synthesis and the release of gonadotropin for egg ovulation and blood chemistry.

## ACKNOWLEDGMENTS

Diane Wakkinen and Jeremy Carlson with IDFG and other temporary employees of IDFG assisted with fieldwork and some summary. We appreciate the editorial review comments from Steve Yundt and Brian Gunderman with IDFG, Matt Evenson of Alaska Department of Fish and Game, and Colin Spence of BCMOELP. Thanks to Steve Arndt and Joyce Hutchinson of the Columbia Basin Fish and Wildlife Compensation Program, Bill Westover, Jay Hammond, Colin Spence and other personnel from BCMOELP, as well as Josh Taylor for assisting with and allowing blood collection. Bonneville Power Administration provided funding for this investigation.

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**APPENDICES**

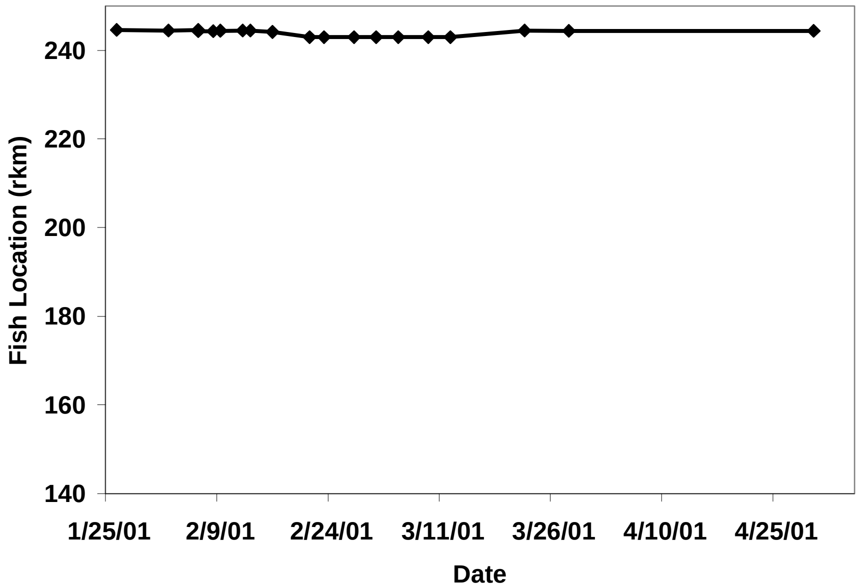
Appendix 1. Capture history of burbot that were recaptured from October 10, 2000 through March 22, 2001.

| FISH # | Recapture | Capture Date | Capture Location (rkm) | TL (MM) | WT (G) | Sex | Notes |
|---|---|---|---|---|---|---|---|
| 180 | FALSE | 03/13/99 | 244.5 | 597 | 1550 | M | Initial capture, flowing milt |
| 180 | TRUE | 01/26/01 | 244.6 | 695 | 2450 | M | Flowing milt |
| 180 | TRUE | 02/06/01 | 244.5 | 694 | 2350 | M | Captured w/ 15 others |
| | | | | | | | |
| 186 | FALSE | 10/29/99 | 207 | 605 | 1290 | M | Initial capture |
| 186 | TRUE | 03/10/00 | 244.5 | 608 | 1325 | M | Flowing, captured w/ 7 others |
| 186 | TRUE | 03/27/00 | 244.4 | | | M | Captured w/ 2 others |
| 186 | TRUE | 10/16/00 | 244.4 | 628 | 1350 | M | Old surgery sutures visible |
| 186 | TRUE | 01/26/01 | 244.6 | 629 | 1550 | M | Mortality, captured w/ 5 others |
| | | | | | | | |
| 196 | FALSE | 01/05/00 | 151.9 | 511 | 860 | U | Initial capture |
| 196 | TRUE | 10/30/00 | 220.5 | 520 | 900 | U | |
| | | | | | | | |
| 205 | FALSE | 02/18/00 | 152.7 | 478 | 710 | M | 0.3 rkm up the Goat R. |
| 205 | TRUE | 02/08/01 | 152.7 | 520 | 975 | M | Captured in Goat R. w/ 6 others |
| | | | | | | | |
| 209 | FALSE | 03/10/00 | 244.5 | 532 | 1010 | M | Flowing captured w/ 7 others |
| 209 | TRUE | 02/06/01 | 244.5 | 538 | 1300 | M | Captured w/ 15 others |
| | | | | | | | |
| 211 | FALSE | 03/10/00 | 244.5 | 662 | 1700 | M | Flowing, captured w/ 7 others |
| 211 | TRUE | 10/16/00 | 244.4 | 662 | 1810 | M | |
| 211 | TRUE | 01/26/01 | 244.6 | 650 | 1725 | M | Captured w/ 5 others |
| 211 | TRUE | 02/06/01 | 244.5 | 657 | 1600 | M | Flowing, captured w/ 15 others |
| 211 | TRUE | 02/09/01 | 244.4 | | | M | Captured w/ 3 others. |
| 211 | TRUE | 02/13/01 | 244.5 | | | M | Captured w/ 15 others |
| | | | | | | | |
| 212 | FALSE | 03/10/00 | 244.5 | 705 | 2850 | M | Flowing, captured w/ 7 others |
| 212 | TRUE | 10/20/00 | 244.4 | 720 | 2450 | M | |
| 212 | TRUE | 10/25/00 | 244.4 | 726 | 2400 | M | |
| 212 | TRUE | 02/06/01 | 244.5 | 735 | 2900 | M | Captured w/ 15 others |
| 212 | TRUE | 02/09/01 | 244.4 | 725 | 2850 | M | Captured w/ 3 others |
| 212 | TRUE | 02/13/01 | 244.5 | 729 | 2750 | M | Captured w/ 15 others. |
| | | | | | | | |
| 214 | FALSE | 03/10/00 | 244.5 | 594 | 600 | M | Flowing, captured w/ 7 others |
| 214 | FALSE | 02/06/01 | 244.5 | 530 | 900 | M | Flowing, captured w/ 15 others |
| 214 | TRUE | 02/13/01 | 244.5 | 530 | 900 | M | Captured w/ 15 others |
| | | | | | | | |
| 218 | FALSE | 11/01/00 | 244.6 | 552 | 1100 | F | Initial capture |
| 218 | TRUE | 01/29/01 | 244.4 | 568 | 1400 | F | Sonic tag added-325 |
| 218 | TRUE | 02/06/01 | 244.5 | 560 | 1140 | F | Captured w/ 15 others. |
| | | | | | | | |
| 225 | FALSE | 01/26/01 | 244.6 | 530 | 1025 | M | Captured w/ 5 others, flowing |
| 225 | TRUE | 02/06/01 | 244.5 | 530 | 1050 | M | Captured w/ 15 others |
| 225 | TRUE | 02/13/01 | 244.5 | 539 | 1050 | M | Captured w/ 15 others |
| | | | | | | | |
| 227 | TRUE | 01/26/01 | 244.6 | 735 | 2700 | F | Captured w/ 4 others |
| 227 | TRUE | 02/06/01 | 244.5 | 745 | 2175 | F | Captured w/ 15 others |
| 227 | TRUE | 03/09/01 | 240.4 | 745 | 2250 | F | Stitches healing well |

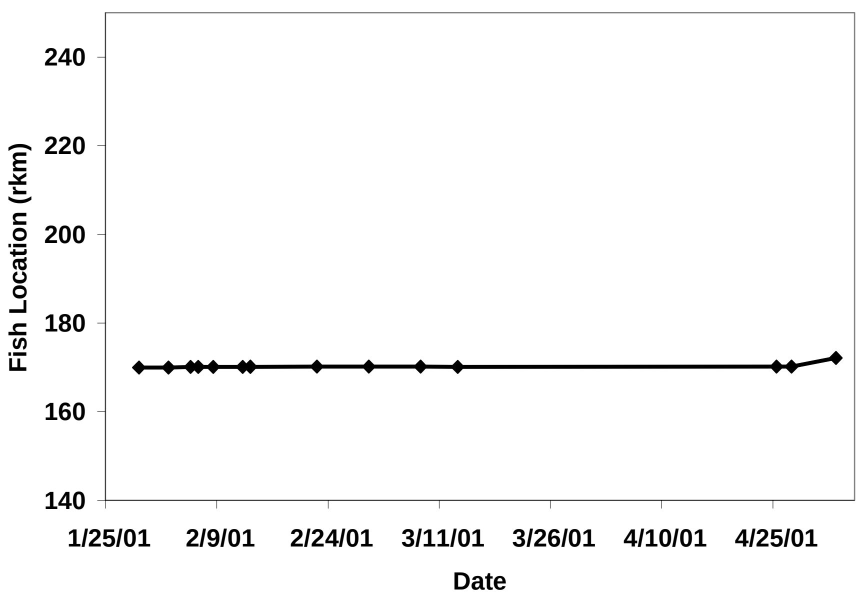
Appendix 1. Continued.

| FISH # | Recapture | Capture Date | Capture Location (rkm) | TL (MM) | WT (G) | Sex | Notes |
|---|---|---|---|---|---|---|---|
| 235 | FALSE | 02/06/01 | 244.5 | 626 | 1950 | U | Captured w/ 15 others |
| 235 | TRUE | 02/13/01 | 244.5 | 624 | 2060 | U | Captured w/ 15 others |
| 236 | FALSE | 02/06/01 | 244.5 | 545 | 1175 | U | Initially captured w/ 15 others |
| 236 | TRUE | 02/13/01 | 244.5 | 552 | 1250 | U | Captured w/ 15 others |
| 237 | FALSE | 02/06/01 | 244.5 | 512 | 1350 | U | Initially captured w/ 15 others |
| 237 | TRUE | 02/09/01 | 244.4 | 525 | 1100 | U | Captured w/ 3 others |
| 238 | FALSE | 02/06/01 | 244.5 | 400 | 400 | F | Flowing captured w/ 15 others |
| 238 | TRUE | 03/15/01 | 244.4 | 400 | 400 | F | |
| 240 | FALSE | 02/06/01 | 244.5 | 612 | 1390 | M | Captured w/ 15 others |
| 240 | TRUE | 02/13/01 | 244.5 | | | M | Captured w/ 15 others |
| 241 | FALSE | 02/06/01 | 244.5 | 530 | 1220 | M | Captured w/ 15 others |
| 241 | TRUE | 02/13/01 | 244.5 | 534 | 1200 | M | Captured w/ 15 others |
| 242 | FALSE | 02/06/01 | 244.5 | 512 | 1050 | M | Captured w/ 15 others |
| 242 | TRUE | 02/13/01 | 244.5 | 522 | 1000 | M | Captured w/ 15 others |
| 243 | FALSE | 02/06/01 | 244.5 | 475 | 600 | M | Captured w/ 15 others |
| 243 | TRUE | 02/13/01 | 244.5 | 475 | 600 | M | Captured w/ 15 others |
| 246 | FALSE | 02/09/01 | 244.4 | 627 | 2100 | U | Initially captured w/ 3 others |
| 246 | TRUE | 02/13/01 | 244.5 | 637 | 1550 | U | Captured w/ 15 others, spent |

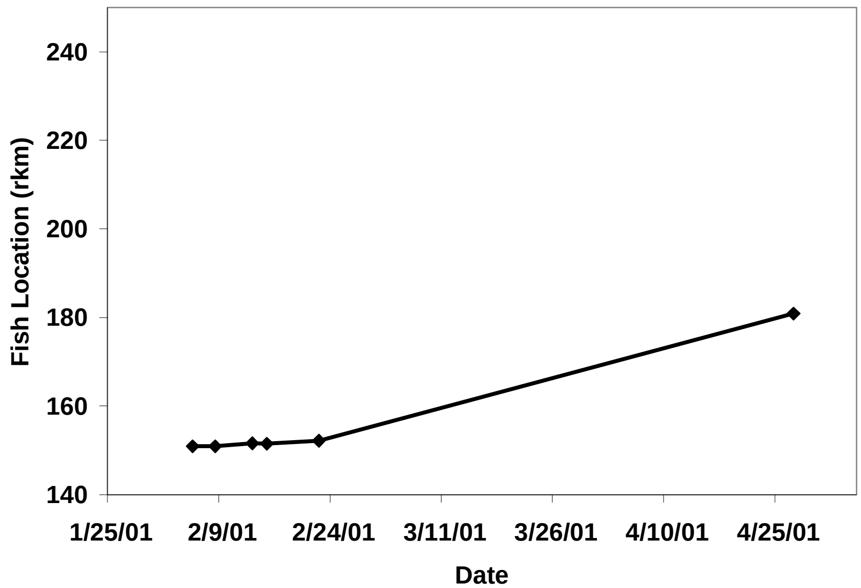
Appendix 2. Movement of sonic-tagged burbot (Fish #211) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



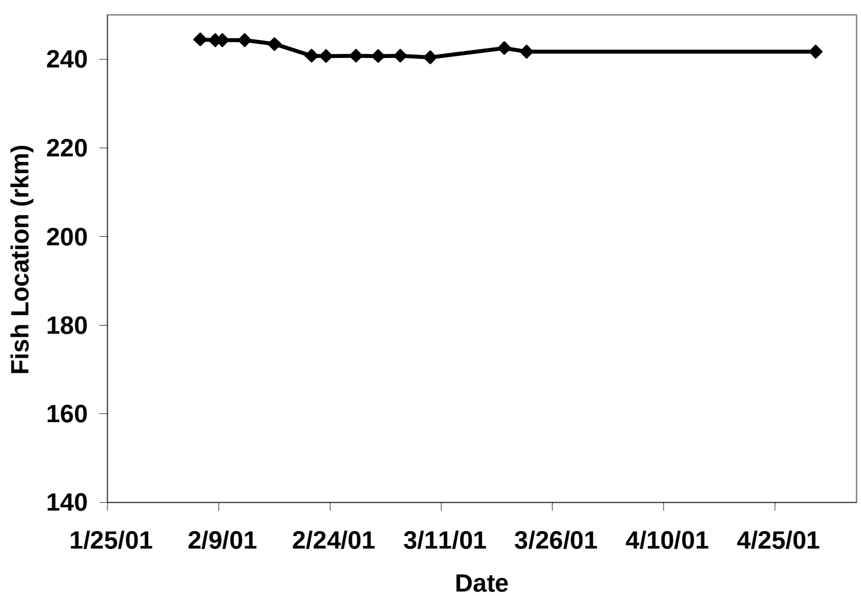

Appendix 3. Movement of sonic-tagged burbot (Fish #230) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



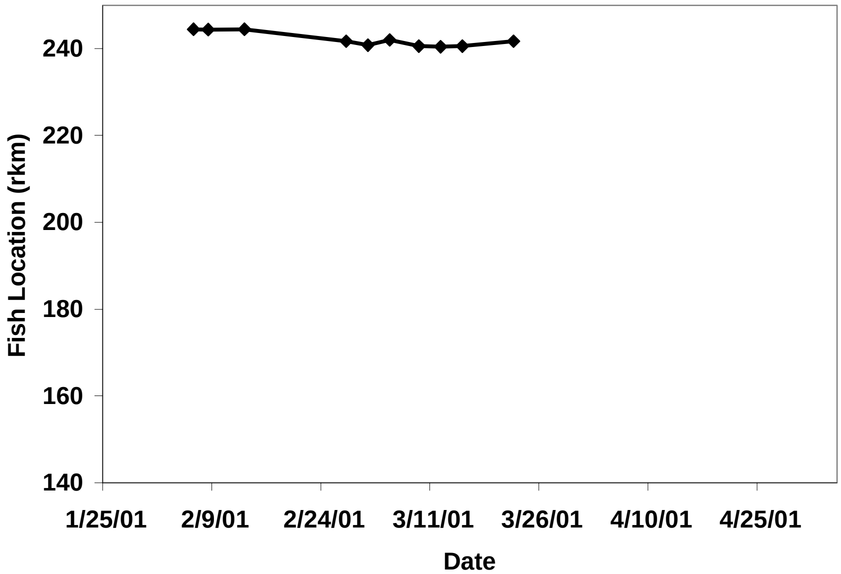
Appendix 4. Movement of sonic-tagged burbot (Fish #233) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



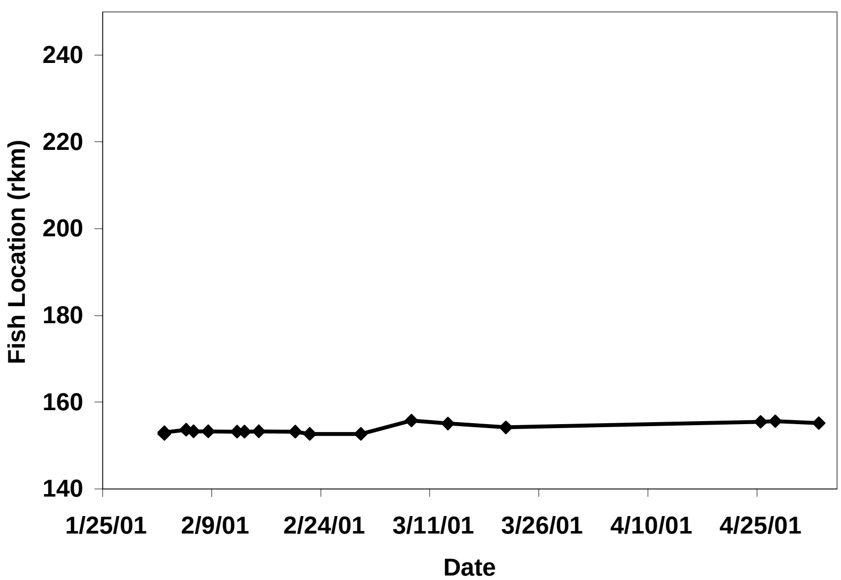

Appendix 5. Movement of sonic-tagged burbot (Fish #227) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



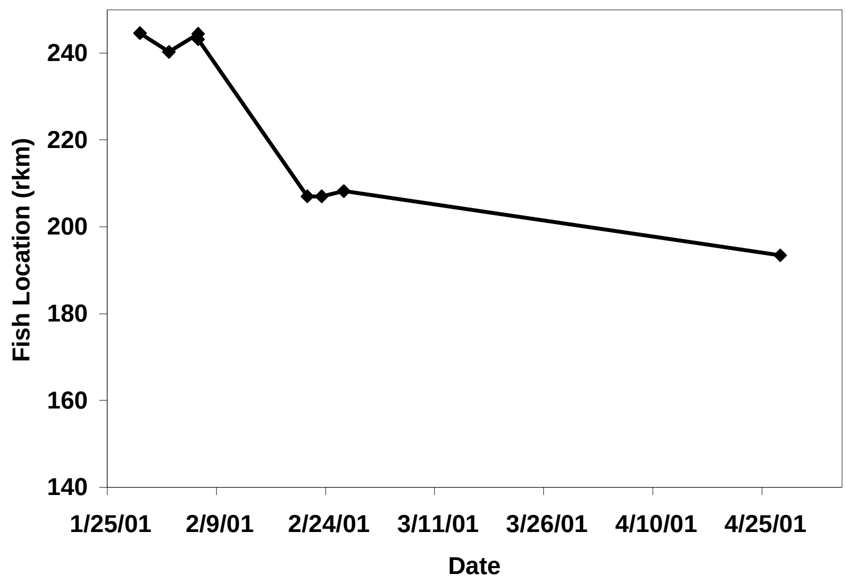
Appendix 6. Movement of sonic-tagged burbot (Fish #240) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



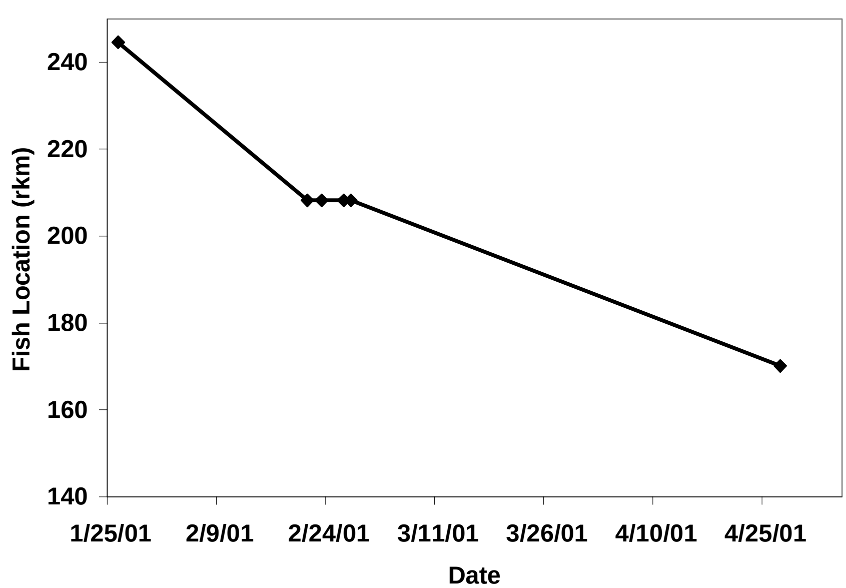

Appendix 7. Movement of sonic-tagged burbot (Fish #232) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



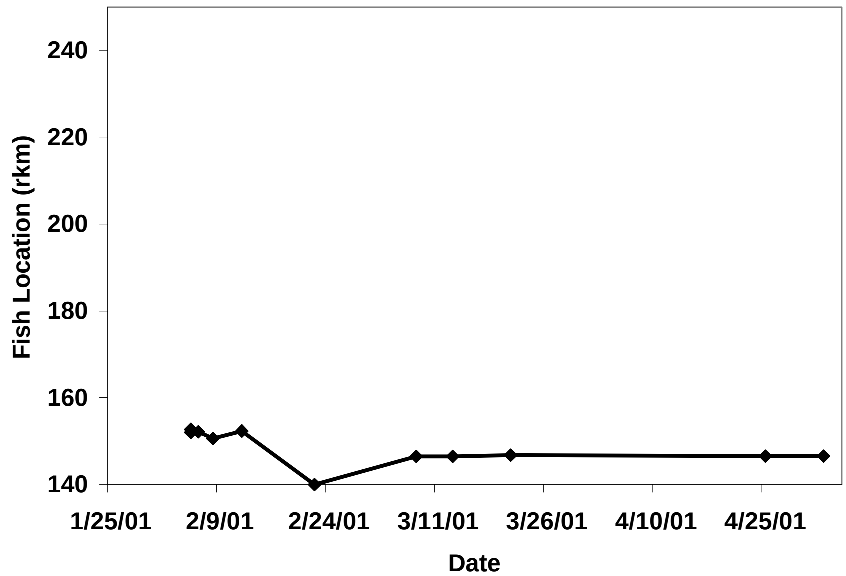
Appendix 8. Movement of sonic-tagged burbot (Fish #218) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



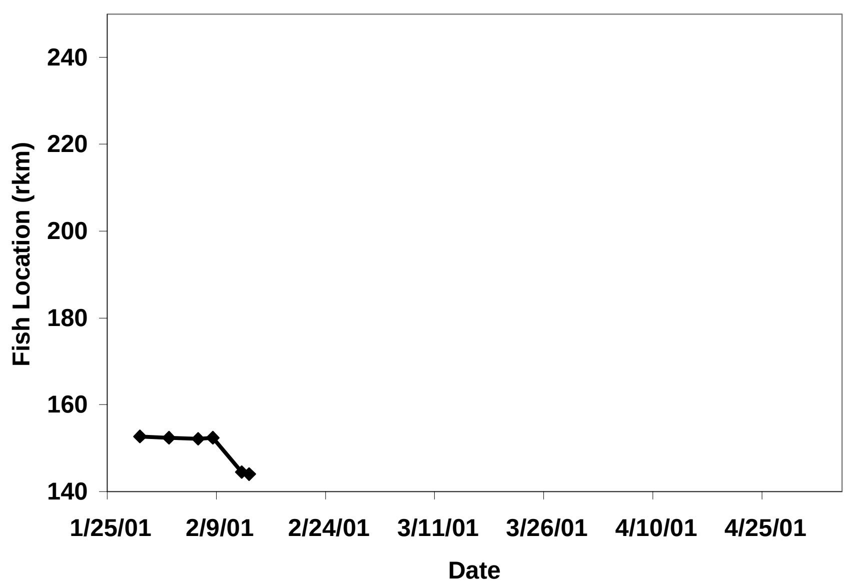

Appendix 9. Movement of sonic-tagged burbot (Fish #226) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



Appendix 10. Movement of sonic-tagged burbot (Fish #234) in the Kootenai River from January through May 2001. Diamonds represent actual location points.




Appendix 11. Movement of sonic-tagged burbot (Fish #231) in the Kootenai River from January through May 2001. Diamonds represent actual location points.



Appendix 12. Location, date, velocity, water temperature, and depth of burbot 211, sonic 2239, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 01/26/01 | 244.6 | 20.42 | 67 | 3.0 |
| 02/02/01 | 244.5 | | | 3.0 |
| 02/06/01 | 244.6 | 20.12 | 66 | 3.0 |
| 02/06/01 | 244.3 | | | |
| 02/08/01 | 244.3 | | | 2.0 |
| 02/09/01 | 244.5 | 16.76 | 55 | 4.0 |
| 02/09/01 | 244.4 | | | 3.5 |
| 02/12/01 | 244.5 | | | |
| 02/13/01 | 244.5 | 20.12 | 66 | 3.5 |
| 02/16/01 | 244.2 | | | 3.5 |
| 02/21/01 | 243.0 | | | 3.5 |
| 02/23/01 | 243.0 | | | 3.5 |
| 2/2/7/01 | 243.0 | | | 2.0 |
| 03/02/01 | 243.0 | | | |
| 03/05/01 | 243.0 | | | 3.0 |
| 03/09/01 | 243.0 | | | 4.5 |
| 03/12/01 | 243.0 | | | 3.5 |
| 03/22/01 | 244.5 | | | 5.0 |
| 03/28/01 | 244.4 | | | 4.5 |
| 04/30/01 | 244.4 | | | 6.8 |
| 05/03/01 | 238.5 | | | 6.0 |
| 05/04/01 | 238.5 | | | 7.5 |
| 05/07/01 | 237.3 | | | 7.5 |
| 05/08/01 | 237.6 | | | 7.5 |
| 05/09/01 | 238.2 | | | 8.0 |
| 05/10/01 | 239.0 | | | 8.5 |
| 05/11/01 | 239.0 | | | 9.0 |
| 05/15/01 | 236.3 | | | 8.0 |
| 05/16/01 | 233.1 | | | 7.0 |
| 05/17/01 | 230.6 | | | 7.0 |
| 05/18/01 | 229.6 | | | 8.0 |
| 05/21/01 | 231.2 | | | 7.0 |
| 05/23/01 | 229.6 | | | 10.0 |
| 05/24/01 | 236.5 | | | 11.0 |
| 05/25/01 | 244.3 | | | 12.0 |
| 05/26/01 | 237.5 | | | 11.0 |
| 05/27/01 | 229.5 | | | 11.0 |
| 05/28/01 | 233.5 | | | 11.0 |
| 05/29/01 | 229.9 | | 25 | |
| 05/30/01 | 236.3 | | | 9.0 |
| 06/04/01 | 234.2 | | | 8.0 |
| 06/07/01 | 236.1 | | | 9.5 |
| 06/11/01 | 227.0 | | | 11.0 |
| 06/18/02 | 231.3 | | | 11.0 |
| 06/24/01 | 245.4 | | | 16.0 |
| 07/19/01 | 237.3 | | | 14.0 |

[a] Date of capture, radio transmitter implant, and release.

Appendix 13. Location, date, velocity, water temperature, and depth of burbot 218, sonic 325, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 01/29/01 | 244.6 | 15.85 | 52 | 3.0 |
| 02/02/01 | 240.3 | | | 3.0 |
| 02/06/01 | 244.5 | 20.12 | 66 | 3.0 |
| 02/06/01 | 243.2 | | | |
| 02/21/01 | 207.0 | | | 3.5 |
| 02/23/01 | 207.0 | | | 3.5 |
| 02/26/01 | 208.2 | 27.43 | 90 | |
| 04/27/01 | 193.4 | 27.43 | 90 | 9.0 |
| 05/30/01 | 190.3 | | | 9.5 |
| 06/04/01 | 191.0 | | | 8.0 |
| 06/18/01 | 181.5 | | | 11.0 |

Appendix 14. Location, date, velocity, water temperature, and depth of burbot 226, sonic 3334, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 01/26/01 | 244.6 | 20.42 | 67 | 3.0 |
| 02/21/01 | 208.2 | | | 3.5 |
| 02/23/01 | 208.2 | | | 3.5 |
| 02/26/01 | 208.2 | 24.38 | 80 | |
| 02/27/01 | 208.2 | | | |
| 04/27/01 | 170.1 | | | 9.0 |
| 05/03/01 | 170.2 | | | 7.5 |
| 05/30/01 | 157.1 | | | 11.0 |
| 06/18/01 | 170.0 | | | 11.0 |
| 09/13/01 | 177.5 | | | |

Appendix 15. Location, date, velocity, water temperature, and depth of burbot 227, sonic 583, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 02/06/01 | 244.5 | 20.12 | 66 | 3.0 |
| 02/08/01 | 244.3 | | | 2.0 |
| 02/09/01 | 244.3 | | | 3.5 |
| 02/12/01 | 244.3 | | | |
| 02/16/01 | 243.4 | | | 3.5 |
| 02/21/01 | 240.8 | | | 3.5 |
| 02/23/01 | 240.7 | | | 3.5 |
| 02/27/01 | 240.8 | | | 2.0 |
| 03/02/01 | 240.7 | | | |
| 03/05/01 | 240.8 | | | 3.0 |
| 03/09/01 | 240.4 | 4.57 | 15 | 3.0 |
| 03/09/01 | 240.4 | | | 4.5 |
| 03/22/01 | 241.7 | | | 5.0 |
| 04/30/01 | 241.7 | 4.57 | 15 | 6.8 |
| 05/15/01 | 241.7 | | | 8.0 |
| 05/16/01 | 242.0 | | | 7.0 |
| 05/21/01 | 242.0 | | | 7.0 |
| 05/25/01 | 244.2 | | | 12.0 |
| 05/29/01 | 244.2 | | 11 | |
| 06/04/01 | 241.5 | | | 8.0 |
| 06/24/01 | 242.5 | | | 16.0 |
| 08/15/01 | 231.5 | | | |
| 09/11/01 | 223.0 | | | |

Appendix 16. Location, date, velocity, water temperature, and depth of burbot 230, sonic 2228, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 1/29/01 | 170.0 | 19.20 | 63 | 3.0 |
| 2/2/01 | 170.0 | | | 3.0 |
| 2/5/01 | 170.1 | | | 4.0 |
| 2/6/01 | 170.1 | | | 4.5 |
| 2/8/01 | 170.1 | | | 3.5 |
| 2/12/01 | 170.1 | | | 3.0 |
| 2/13/01 | 170.2 | | | 2.5 |
| 2/13/01 | 170.1 | | | 3.5 |
| 2/22/01 | 170.2 | | | 4.0 |
| 3/1/01 | 170.2 | | | |
| 3/8/01 | 170.2 | | | |
| 3/13/01 | 170.1 | | | |
| 5/3/01 | 172.1 | | | 7.5 |
| 5/30/01 | 172.1 | | | 9.0 |
| 6/18/01 | 173.2 | | | 11.0 |
| 9/13/01 | 173.0 | | | |

Appendix 17. Location, date, velocity, water temperature, and depth of burbot 231, sonic 2259, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 01/29/01 | 152.7 | 13.11 | 43 | 3.0 |
| 02/02/01 | 152.4 | | | 3.0 |
| 02/06/01 | 152.2 | | | 4.5 |
| 02/08/01 | 152.4 | | | 3.5 |
| 02/12/01 | 144.5 | | | 3.0 |
| 02/13/01 | 144.0 | | | 2.5 |

Appendix 18. Location, date, velocity, water temperature, and depth of burbot 232, sonic 2249, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 02/02/01 | 152.7[a] | 11.89 | 39 | 3.0 |
| 02/02/01 | 153.1 | | | 3.0 |
| 02/05/01 | 153.7 | | | 4.0 |
| 02/06/01 | 153.3 | | | 4.5 |
| 02/08/01 | 153.3 | | | 3.5 |
| 02/12/01 | 153.2 | | | 3.0 |
| 02/13/01 | 153.2 | | | 2.5 |
| 02/15/01 | 153.3 | | | 3.5 |
| 02/20/01 | 153.2 | | | 1.0 |
| 02/22/01 | 152.7[a] | | | 4.0 |
| 03/01/01 | 152.7[a] | | | |
| 03/08/01 | 155.8 | | | |
| 03/13/01 | 155.1 | | | |
| 03/21/01 | 154.2 | | | 4.0 |
| 04/27/01 | 155.5 | | | 9.0 |
| 05/03/01 | 155.2 | | 25 | 7.5 |
| 05/03/01 | 156.3 | | | 9.0 |

[a] Located in the Goat River.

Appendix 19. Location, date, velocity, water temperature, and depth of burbot 233, sonic 357, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 02/05/01 | 150.9 | 18.59 | 61 | 3.0 |
| 02/08/01 | 150.9 | | | 3.5 |
| 02/13/01 | 151.6 | | | 2.5 |
| 02/15/01 | 151.5 | | | 3.5 |
| 02/22/01 | 152.2 | | | 4.0 |
| 04/27/01 | 180.9 | | | 9.0 |
| 05/17/01 | 229.5 | | | 7.0 |
| 05/18/01 | 230.6 | | | 8.0 |
| 05/21/01 | 233.8 | | | 7.0 |
| 05/23/01 | 234.0 | | | 10.0 |
| 05/24/01 | 237.2 | | | 11.0 |
| 05/26/01 | 234.5 | | | 11.0 |
| 05/30/01 | 233.8 | | | 9.0 |
| 06/04/01 | 231,5 | | | 8.0 |
| 06/07/01 | 234.6 | | | 9.5 |

Appendix 20. Location, date, velocity, water temperature, and depth of burbot 234, sonic 2632, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 02/05/01 | 152.7 | 2.44 | 8 | 3.0 |
| 02/05/01 | 152.0 | | | 4.0 |
| 02/06/01 | 152.2 | | | 4.5 |
| 02/08/01 | 150.6 | | | 3.5 |
| 02/12/01 | 152.3 | | | 3.0 |
| 02/22/01 | 140.0 | | | 4.0 |
| 03/08/01 | 146.5 | | | |
| 03/13/01 | 146.5 | | | |
| 03/21/01 | 146.8 | | | 4.0 |
| 05/03/01 | 146.6 | | 32 | 7.5 |
| 06/05/01 | 147.0 | | | 10.0 |
| 09/18/01 | 147.0 | | | |

Appendix 21. Location, date, velocity, water temperature, and depth of burbot 240, sonic 3344, as determined by sonic telemetry and depth sounder.

| Date | Location (rkm) | Depth (m) | Depth (ft) | Water Temperature (°C) |
|---|---|---|---|---|
| 02/06/01 | 244.5 | 20.12 | 66 | 3.0 |
| 02/08/01 | 244.4 | | | 2.0 |
| 02/13/01 | 244.5 | 20.12 | 66 | 3.5 |
| 02/27/01 | 241.7 | | | 2.0 |
| 03/02/01 | 240.8 | | | |
| 03/05/01 | 242.0 | | | 3.0 |
| 03/09/01 | 240.6 | | | 4.5 |
| 03/12/01 | 240.4 | | | 3.5 |
| 03/15/01 | 240.6 | | | 4.5 |
| 03/22/01 | 241.7 | | | 5.0 |

Appendix 22. Steroid levels of burbot sampled for blood from the Kootenai River from January 26 through March 9, 2001. ND denotes that actual value was below the lower limit of detection.

| FISH # | Date | Depth (m) | TL (mm) | WT (g) | Sex | Testosterone (ng/ml) | 11-Ketotes-tosterone (ng/ml) | Estradiol (ng/ml) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 225 | 01/26 | 20 | 530 | 1025 | M | 44.96 | 81.47 | ND | Released milt |
| 211 | 01/26 | 20 | 650 | 1725 | M | 22.74 | 34.58 | 0.56 | Released milt |
| 186 | 01/26 | 20 | 629 | 1550 | M | 6.09 | 11.3 | 0.60 | Mortality |
| 227 | 01/26 | 20 | 735 | 2700 | F | 15.15 | 3.46 | 0.38 | |
| 226 | 01/26 | 20 | 547 | 1100 | M | 14.31 | 36.64 | ND | Male dissection |
| 229 | 01/29 | 16 | 505 | 620 | U | 1.16 | 1.18 | 0.60 | Light bleeding |
| 225 | 02/06 | 20 | 530 | 1050 | M | 33.90 | 38.44 | ND | |
| 180 | 02/06 | 20 | 694 | 2350 | M | 8.20 | 20.11 | ND | |
| 209 | 02/06 | 20 | 538 | 1300 | M | 19.50 | 39.75 | 1.14 | |
| 242 | 02/06 | 20 | 512 | 1050 | M | 5.62 | 11.62 | ND | |
| 70 | 02/08 | 2 | 508 | 850 | M | 8.73 | 21.76 | 0.44 | Released milt |
| 205 | 02/08 | 2 | 520 | 975 | M | 20.45 | 38.88 | ND | Released milt |
| 245 | 02/08 | 2 | 521 | 825 | M | 3.94 | 15.92 | ND | Released milt |
| 212 | 02/09 | 17 | 725 | 2850 | M | 8.26 | 14.17 | ND | Released milt |
| 247 | 02/13 | 20 | 549 | 1400 | U | ND | ND | 0.39 | |
| 236 | 02/13 | 20 | 552 | 1250 | M | 1.57 | 1.59 | ND | Released milt |
| 246 | 02/13 | 20 | 637 | 1550 | U | 0.69 | ND | 0.36 | Spawned out |
| 235 | 02/13 | 20 | 624 | 2060 | U | 8.48 | 17.97 | 0.35 | |
| 214 | 02/13 | 20 | 530 | 900 | M | 1.38 | 2.64 | ND | Released milt |
| 243 | 02/13 | 20 | 475 | 600 | M | 1.02 | 0.73 | ND | Released milt |
| 251 | 02/13 | 20 | 544 | 1050 | F | 1.13 | ND | 0.59 | |
| 253 | 03/09 | 5 | 730 | 2400 | U | ND | ND | ND | |

Appendix 23. Steroid levels of burbot sampled for blood from Columbia Lake, BC. ND denotes that actual value was below the lower limit of detection.

| FISH # | Date | Depth (m) | TL (mm) | WT (g) | Sex | Testosterone (ng/ml) | 11-Ketotes-tosterone (ng/ml) | Estradiol (ng/ml) | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 411F191B4B | 2/14 | 0.5 | 455 | 600 | M | ND | ND | ND | Partly Spent |
| NA | 2/14 | 0.5 | 590 | | F | ND | ND | ND | Partly Spent |
| 4137056905 | 2/14 | 0.5 | 615 | 1375 | M | 1.42 | 8.64 | ND | Partly Spent |
| 41363F062B | 2/14 | 0.5 | 555 | 1050 | M | 0.44 | ND | 2.62 | Partly Spent |
| 4110222E15 | 2/14 | 0.5 | 511 | 1025 | F | 0.45 | 2.1 | ND | Ripe |
| 4136405876 | 2/14 | 0.5 | 582 | 1075 | M | ND | ND | ND | Spent |
| 41370D791C | 2/14 | 0.5 | 458 | 975 | U | 0.50 | ND | ND | Gravid |
| 4136171502 | 2/14 | 0.5 | 477 | 900 | F | ND | ND | ND | Ripe |
| 413678297D | 2/14 | 0.5 | 555 | 1150 | U | ND | 3.7 | 0.42 | Spent |
| 4136386C5C | 2/14 | 0.5 | 425 | 600 | M | 0.33 | ND | 0.43 | Spent |
| 411F15020B | 2/14 | 0.5 | 475 | 625 | M | 0.44 | ND | ND | Partly Spent |
| 413721061F | 2/14 | 0.5 | 446 | 650 | M | 1.13 | 1.42 | ND | Spent |
| 41370E0848 | 2/14 | 0.5 | 340 | 250 | M | 0.52 | ND | 0.67 | Spent |
| 411F19764E | 2/14 | 0.5 | 348 | 325 | M | 0.34 | ND | 0.40 | Spent |
| 41367D5C58 | 2/14 | 0.5 | 658 | 1775 | U | 0.49 | ND | ND | Spent |
| 4137156B6D | 2/14 | 0.5 | 482 | 750 | U | 1.58 | ND | ND | Spent |
| 413708047F | 2/14 | 0.5 | 388 | 450 | U | ND | ND | ND | Spent |

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